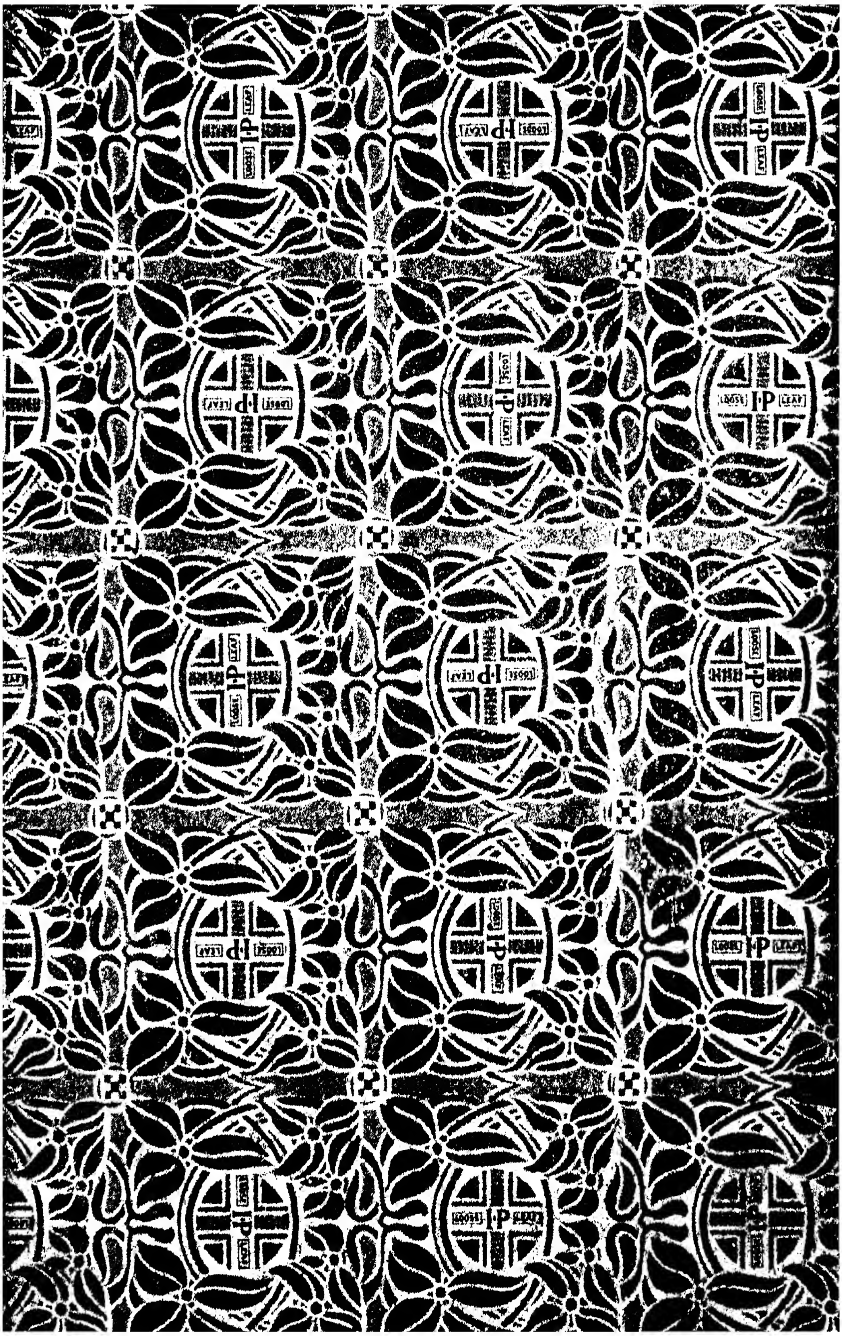
LOOSE
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RESEARCH IN THE DEVELOPMENT

of

CYANOGAS CALCIUM CYANIDE

FOREWORD

The American Cyanamid Company presents, in the following pages, data obtained in research work with Cyanogas Calcium Cyanide for the control of various animal pests. These data are of three sources: first, the work of various research men employed by the Company; second, reports of interesting developments arising in the work of various investigators*; third, exact reprints of publications of a scientific nature dealing with Cyanogas Calcium Cyanide. The experiments are grouped into sections of closely related subjects. As new data are obtained and new articles appear in print, new pages will be printed and sent to those receiving the original booklet. These pages are to be inserted in the booklet at their proper places as designated by section and page numbers. In this way the Company hopes to keep experimental workers informed of all the latest developments relating to the uses of Cyanogas Calcium Cyanide.

*Such information will not be published unless authorized by the worker.

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SECTION G

GENERAL INFORMATION

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Note: In December, 1925, the name, American Cyanamid Company of Delaware was changed to American Cyanamid Sales Company, which Company deals with all matters pertaining to insecticides manufactured by the American Cyanamid Company of Maine.

Nature of Cyanogas Calcium Cyanide

Cyanogas Calcium Cyanide is made from the nitrogen of the air. Calcium Cyanamid, with the formula $CaCN_2$ is first made and Calcium Cyanide $Ca(CN)_2$ is made from the Cyanamid. Calcium Cyanide is perfectly distinct from Cyanamid, having an extra carbon atom and totally different characteristics.

When Calcium Cyanamid is acted upon, by moisture, urea is formed, whereas when Calcium Cyanide is acted upon by atmospheric water vapor, hydrocyanic acid is given off.

$$CaCN_2+3H_2O=Ca(OH)_2+CO(NH_2)_2$$

$$Ca(CN)_2+2H_2O=Ca(OH)_2+2HCN$$

The use of Cyanogas Calcium Cyanide as a rodenticide, insecticide, and vermicide depends upon this reaction. It has been well known for many years that hydrocyanic acid gas was an effective economic poison, but its use was limited by the necessity of generating the gas by the action of acid and water upon sodium or potassium cyanide in regular fumigating pots or jars.

The production of liquid hydrocyanic acid was a step in the direction of ease of application, but the use of Cyanogas Calcium Cyanide has made possible the use of hydrocyanic acid as a killing agent in many fields where neither sodium cyanide or liquid hydrocyanic acid could ever be used.

Grades

Cyanogas Calcium Cyanide is manufactured in a number of different grades, adapted for various problems. During the development of the work certain grades were used in experiments which are no longer manufactured. The names of the grades have also been changed. The following list of grades is designed to describe those in use now and those which were made in the past but are no longer manufactured. Names in bold faced type are the current names of the grades.

GRADES OF CYANOGAS NOW MANUFACTURED

Cyanogas Chinch Bug Flakes—Calcium Cyanide Flakes, containing not less than 40% nor more than 50% Calcium Cyanide. Large pieces about 1/32 of an inch in thickness.

Cyanogas Calcium Cyanide Granules—containing not less than 40% nor more than 50% Calcium Cyanide. A coarse granular material.

CYANOGAS G—FUMIGANT—Cyanogas Calcium Cyanide "G" Grade, containing not less than 40% nor more than 50% Calcium Cyanide. Particles very small, about like sea sand.

CYANOGAS CALCIUM CYANIDE "A" DUST—containing not less than 40% nor more than 50% Calcium Cyanide. A fine dust, about 80% passing through a 200 mesh screen.

CYANOGAS S—DUSTING MIXTURE—Sulphur Cyanide—containing not less than 17% nor more than 25% Calcium Cyanide; 50% Sulphur. A fine dust.

CYANOGAS CALCIUM CYANIDE CITRUS DUST—containing not less than 30% nor more than 37.5% Calcium Cyanide; 25% Sulphur. A fine dust.

OBSOLETE NAMES

CYANOGAS Calcium Cyanide "B" Dust, a mixture consisting of "A" Dust and 50% of talc as a diluent. A fine dust.

Calcium Cyanide "C" Dust, a mixture consisting of "A" Dust and 75% of talc as a diluent. A fine dust.

Gas Flakes, a name employed for Cyanogas Chinch Bug Flakes.

Fumo Brand a trade name used in Australia.

USES OF CYANOGAS CALCIUM CYANIDE

Cyanogas Calcium Cyanide is used in many different ways depending upon the pest to be controlled. These methods may be roughly divided into five groups.

1. The Fumigation of Enclosed Spaces.
   Examples: Dwelling houses,* greenhouses or glass-houses, trees enclosed in tents.
2. The Destruction of Burrowing Animals.
   Examples: Rodents, moles, crayfish, land crabs, land turtles, termites, ants.
3. Treatment of Subterranean Insects and Worms.
   Examples: Wireworms, white grubs, nematodes.
4. Open Air Dusting.
   Examples: Aphids, capsids, psyllids.
5. A poisonous barrier for migrating animals.
   Examples: Chinch bugs, army worms, locusts.

*Cyanogas must not be used for fumigating dwellings except where the work is performed by or under the supervision of professional or licensed fumigators.

The Evolution of Hydrocyanic Acid Gas From Cyanogas Calcium Cyanide

The factors which might affect the evolution of hydrocyanic acid gas from Cyanogas Calcium Cyanide fall into two groups. One group is concerned with the condition of the air to which the cyanide is exposed and includes such factors as temperature and relative humidity. The second group includes particle size and thickness of the layer exposed; that is, those concerned with the physical and mechanical condition of the cyanide.

In the first series of experiments the effects of relative humidity and temperature were studied. In order to eliminate, as far as possible, the effect of particle size, this series was run with Cyanogas "A" Dust. The sample was also exposed in layer thin enough to reduce to a minimum the effect the thickness of the layer might have. One gram of the Cyanogas Calcium Cyanide was spread out in the reaction flask, which had previously been thoroughly dried. Air conditioned as to humidity and temperature was passed through this flask at the rate of 1.3 cu. ft. per hour into a caustic soda scrubber where the evolved hydrocyanic acid gas was absorbed.

Since Cyanogas Calcium Cyanide is dependent upon atmospheric water vapor for the reaction in which hydrocyanic acid is given off, a relationship between the percentage of gas evolved in a given time and the relative humidity of the atmosphere might be expected. Experiments under these conditions have shown that if the relative humidity is above 35% the rate of evolution of hydrocyanic acid gas is independent of the relative humidity, the major portion being evolved in the first hour. If the relative humidity is lower than 30%, the evolution of the gas is retarded. This may best be illustrated by Fig. 1, which was plotted from data obtained under these controlled conditions. It will be noted from this figure that where the relative humidity is 50% or above, 90% of the available hydrocyanic acid is evolved in the first two and one-half hours of exposure. An interesting fact is also emphasized by the run made at 25% relative humidity for three hours and continued at 95% relative humidity for an additional two and one-half hours. The in-

crease in humidity, shown by the abrupt break in the curve, produced an evolution of gas practically identical with what it would have been had the run started at 95%. During the first hour of this run the evolution of hydrocyanic acid gas was much more rapid than during the second hour. During the first hour a thin layer of calcium hydroxide would be formed around the particle which might prevent the atmospheric moisture, under conditions of low relative humidity, from reacting with the Calcium Cyanide on the interior of the particle, but would not prevent this reaction at high relative humidities.

The experiments indicated that the evolution of the gas was not materially affected by changes of temperature, providing there was sufficient moisture in the air to produce the reaction.

The experiments dealing with the physical and mechanical condition of the Cyanogas Calcium Cyanide showed that the amount of hydrocyanic acid gas evolved in a given time was a function of the surface of the Calcium Cyanide exposed. Cyanogas "A" Dust, under controlled conditions, evolved about twice as much hydrocyanic acid in four hours as did the Cyanogas flakes. Cyanogas Calcium Cyanide granules and "G" Fumigant occupied intermediate positions. It was also found that the evolution of hydrocyanic acid gas from Cyanogas "A" Dust was a function of the surface exposed and not of the quantity. Thus a charge of Cyanogas "A" Dust spread out in a layer 1/16 of an inch in thickness gave a higher concentration than the same quantity of "A" Dust spread out in a layer 1/8 of an inch thick and this, in its turn, gave a higher concentraton than a layer 1/4 of an inch thick.

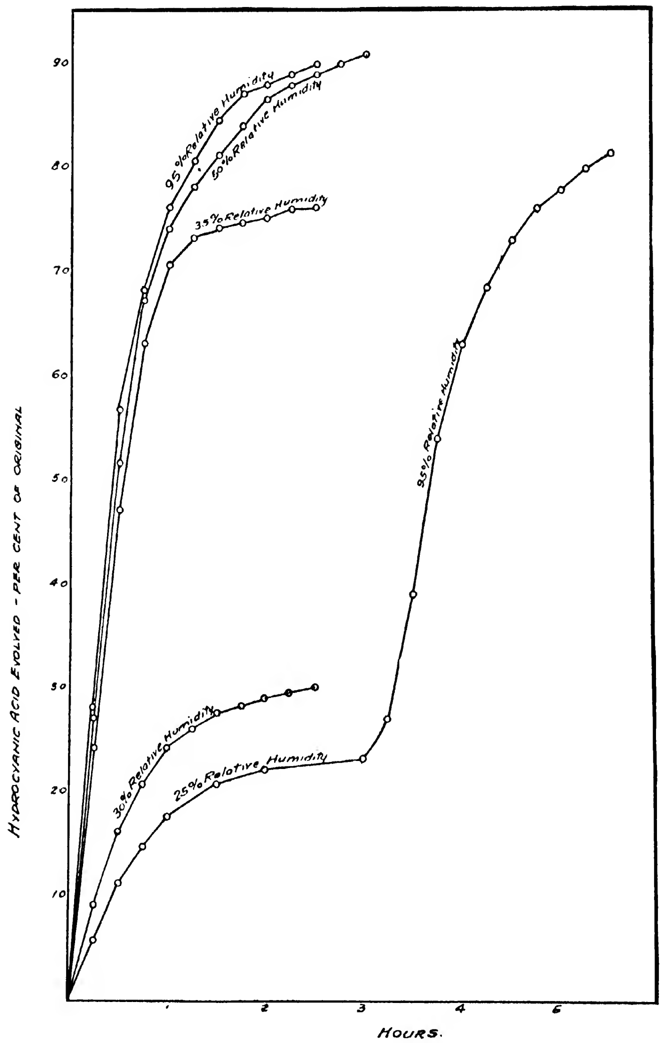

FIG. 1.—Evolution of Hydrocyanic Acid from Cyanogas "A" Dust at 22°C.

SECTION 1

FUMIGATION—TENT

Citrus Fumigation With Calcium Cyanide

In 1886 the first fumigations of citrus trees were conducted in California by acting upon potassium cyanide with sulphuric acid in fumigating jars. In later work sodium cyanide was substituted for potassium cyanide, and more recently liquified hydrocyanic acid came into commercial use. The use of Calcium Cyanide as a source of hydrocyanic acid gas is the latest and most modern method of fumigating citrus trees.

EFFECTIVENESS OF HYDROCYANIC ACID FUMIGATION

Fumigation with hydrocyanic acid gas is recognized as the most effective method of control for the numerous scale insects infesting citrus trees. Professor R. S. Woglum in Farmers' Bulletin No. 1321 of the United States Department of Agriculture says: "The use of hydrocyanic acid gas in fumigating plants for the destruction of insect pests is one of the most important discoveries in the field of insect control. No other known gas having so wide a range of usefulness so quickly destroys insect life. Nearly every year new sprays have been offered in competition with the gas method, but fumigation has outlived them all and hydrocyanic acid gas is today, even as thirty years ago, by far the most widely used and most effective of all insecticides for scale control on citrus trees on the Pacific coast."

Hydrocyanic acid gas is now used for scale control in United States, Australia, South Africa, Egypt, Spain, Palestine and Japan.

HOW TO FUMIGATE

EQUIPMENT FOR COVERING THE TREES

When citrus trees are to be fumigated they are covered by a canvas tent to retain the hydrocyanic acid gas for the necessary period of time. Flat cloth tents are used. These should be of a tight weave, light in weight, but of sufficient strength to prevent tearing in covering the trees. In the United States a special, closely woven eight-ounce duck is used. To avoid excessive weight, 40 foot tents or larger may be constructed from eight-ounce duck centers and the "wings" or "skirts" of seven-ounce duck or drill. The tents are square or octagonal in shape. Several different sizes are necessary to accommodate the trees of various dimensions. The most common tents used in the United States are 36, 41, 43, 45, 48, 50, 52, 55, 64, 72, and 81 feet between the parallel sides.

In order that the distance over the top of the tree may be read directly, the tents are usually marked in feet, as shown in Fig. 4-1. The marks should only be put on after the tent cloth has been shrunken by spreading it out flat in the open and saturating it with water.

Two poles are used in pulling the tents over the trees. They should be about 2 inches in diameter and from 14 to 18 feet in length.

The pulling ropes which are attached to the top of the pole should be 3/4 to 1 inch in diameter and about 3 feet longer than the pole with which it is to be used.

HOW TO COVER A TREE WITH THE TENT

Lay the tent out beside the tree. To prevent the seams of the tent from pulling apart, it should be arranged so that it is pulled in the same direction as the seams run. At each side make a double lap of the tent over the end of the pole and attach it to the pole by a half hitch of the rope. After the tent is thus attached the bottom of the poles are held in place by the foot of the operators while they pull the tent up. They then gradually move backward as the tent comes over the top of the tree and falls in place. The bottom of the tent should be kicked in and should be close to the ground at all points. This procedure of placing the tent over a tree is illustrated in Fig. 1-1.

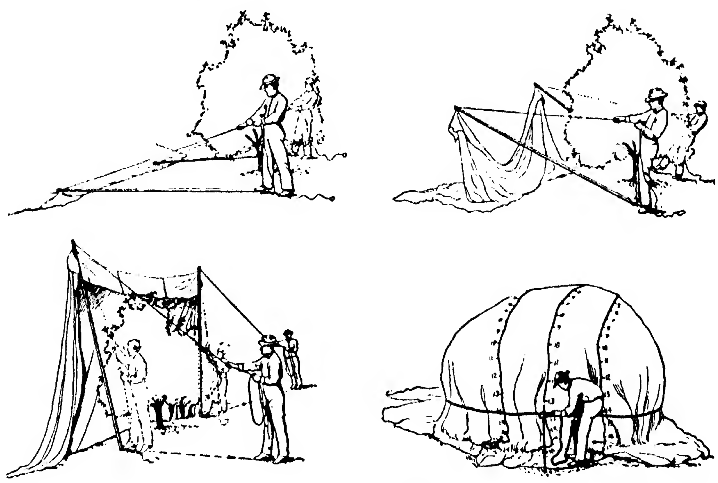

FIG. 1-1—Successive stages in placing a tent over a tree with poles. (After Woglum, U. S. D. A. Farmers' Bulletin 1321).

Fig. 2-1—Leaves of Orange Tree from Attack of Aphis (*Aphis spiraecola*), Orlando, Florida.

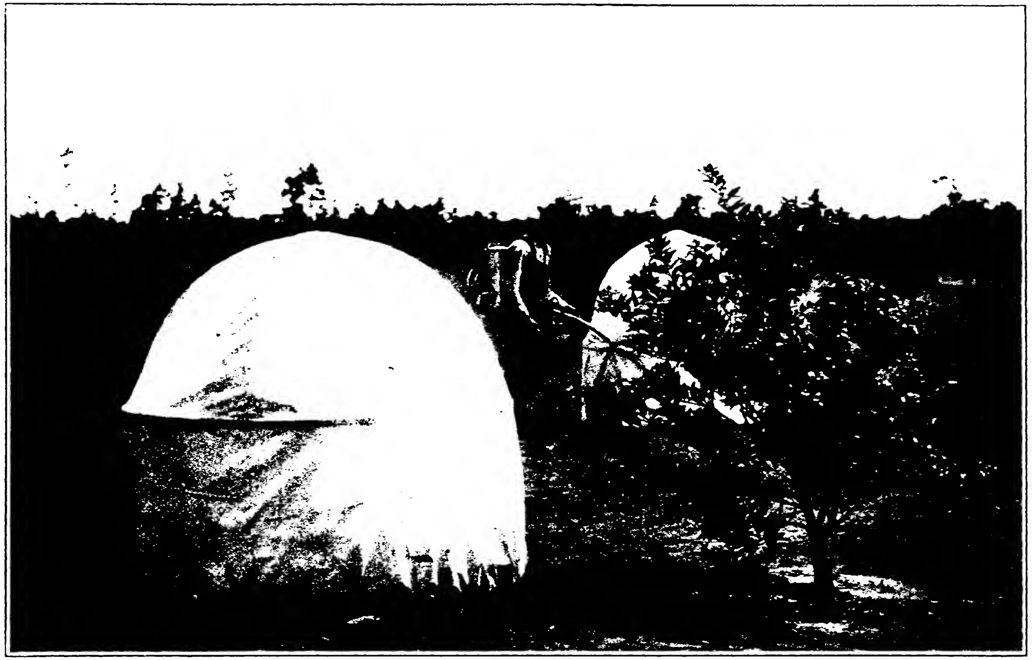

FIG. 3-1.—Short-period Fumigation of Orange Trees under Tents for Aphids, Orlando, Florida.

HOW TO MEASURE THE TREE AND TO DETERMINE THE DOSAGE

The amount of material necessary to fumigate a given tree is determined by measuring the distance over the top of the tent and the distance around the bottom. The distance over the top may be measured by a tape line or by the marked tent previously described. When a marked tent is used the line should pass directly over the top of the tree. Read the numbers where the line touches the ground on the opposite sides of the tree. The sum of these two numbers is the distance over the top.

The distance around the bottom is measured by a tape held about 3 feet above the ground. Pacing the distance around the tent is *not sufficiently accurate.* After the distance over and the distance around have been measured, the proper dosage is determined by referring to a dosage chart. Such charts were developed after years of experimental work by determining the amount of sodium cyanide to use per 100 cubic feet of tent space which would furnish efficient insect control with safety to the tree. Using this amount as a standard, the dosages required for different sizes of trees were charted on the basis of the distance over and the distance around the tree. These charts have served as the basis for commercial fumigation with sodium cyanide. When liquified hydrocyanic acid was developed the same dosage charts were used. The figures given in these charts in terms of ounces of sodium cyanide are also used to designate units of liquified hydrocyanic acid, each unit consisting of 18 cc.

DUST FUMIGATION OF CITRUS TREES

Professor H. J. Quayle of the Citrus Experiment Station, Riverside, California, conducted experiments with Cyanogas Calcium Cyanide Dust for fumigation of citrus trees in August and September, 1922. This was accomplished by blowing the finely powdered Cyanogas Calcium Cyanide under tented orange and lemon trees. The note indicating the results of this preliminary work appeared in The Journal of Economic Entomology, Vol. 16, No. 3, page 327, June 1923, and is reproduced together with a second note referring to these experiments which appeared in the Report of College of Agriculture and Experiment Station, University of California, July 1, 1922, to June 30, 1923, p. 99.:

Calcium Cyanide Dust as an Insecticide. In August and September, 1922, 25 or 30 orange and lemon trees were fumigated by blowing finely powdered calcium cyanide under tented trees to determine the effect of such material on citrus trees and on the scale insects infesting them. The trees were infested with the black, red and citricola scales and a complete kill of these scales was effected without any injury to the trees. Other trees were fumigated in the same way later in the season when rains and moist weather followed with the result that, while the scales were killed, some injury to the trees was apparent. The injury, however, appeared to be only temporary. During a dry period in January, one or two other trees were fumigated without injury. Moisture seems to be an important factor in connection with the possible use of powdered calcium cyanide as a tree fumigant, and further work to determine its effect is now in progress.

Powdered calcium cyanide has also been used as a soil fumigant, and results thus far indicate that this form of cyanide is well adapted for soil fumigation. Hydrocyanic acid gas is readily given off and the powder is easily applied in the soil. It would be possible to apply it in the soil on a large scale by means of a drill. Woolly aphis and other soil infesting insects have been killed with the use of 2 oz. per sq. yd. Little has been determined thus far as to the effect of the powder on the roots of trees but the indications are that it is less injurious than a solution of any form of cyanide.

A few preliminary experiments have also been made with the peach root-borer. Where the material was applied directly to the tree a good kill of the borers resulted, but the effects on the tree remain to be determined. It is also planned to make tests against nematodes where these occur with normal crops. It has already been used with considerable success against ground squirrels. The University of California Citrus Experiment Station is engaged in an investigation of the uses of powdered calcium cyanide as an insecticide and, at the present time, the work has proceeded far enough to indicate merely some of the possibilities rather than to make any definite claims supported by sufficient data.

H. J. Quayle, *Citrus Experiment Station, Riverside, Calif.*

Fumigation with Calcium Cyanide Dust.—A new system of fumigation for the control of scale pests on citrus trees has been developed by H. J. Quayle and H. Knight, assisted by F. C. Greer. This consists in discharging under a tented citrus tree, by means of a suitable dusting machine, a given quantity of finely pulverized calcium cyanid $Ca(CN)_2$. The dust fills the entire tented area, each minute particle giving off hydrocyanic acid gas. Unlike present fumigation methods with liquid HCN in which the gas becomes increasingly

diluted with air as it diffuses through the tent and thus does not reach the insect at its highest concentration, calcium cyanid dust generates HCN gas at the point of contact with the scale. The gas is generated gradually and uniformly in all parts of the tent at once, reaching its highest concentration in about 40 minutes, although after the first five minutes the concentration increases only slightly. A killing concentration is thus maintained throughout the entire exposure. Trees infested with black, citricola, and red scale when fumigated by this method in dry weather, were entirely freed of scale and showed no injurious effect.

Moisture seems to be a limiting factor, however, in the possible use of calcium cyanid dust as a tree fumigant. Burning and heavy leaf drop have occurred when rain followed the fumigation. The injury, however, appeared to be only temporary. Tests are being undertaken to determine whether this tendency to injury can be overcome; if not, then the use of this dust will be limited to sections where dry atmospheric conditions prevail.

Early in 1923 Professor Quayle went to Australia to conduct experiments with Calcium Cyanide and the work in California was continued by our Mr. E. R. Hulbirt. He defined the conditions of temperature and moisture under which dust fumigation of oranges and grape fruit might be safely conducted in certain sections of California, and the dosage required. In a series of experiments analyses were made for HCN present in the dust residue remaining on the leaves of fumigated trees. The samples were collected after the tents were removed, in 2 hours, and in 5 hours. The average amount of HCN was found to be 2% or less at the time the tents were pulled. He found that the cyanide content of the residue was noticeably higher in late afternoon and evening than it was for the earlier part of the day. This result did not seem to have any relation either to the relative humidity or the temperature. Another peculiarity was the fact that the injury to orange trees had no apparent relation to the cyanide content of the residue either at the time the tent was removed, or at the time dew was formed on the trees.

DOSAGE TABLES FOR CYANOGAS CALCIUM CYANIDE DUST

In the early fumigation work with Cyanogas Calcium Cyanide the dosage required for a tree was determined on the basis of the dosage tables for liquified hydrocyanic acid then in use in California. It was felt that the dosages of Calcium Cyanide Dust which should be used would be as large as those used for the liquified hydrocyanic acid since the active fumigant in each case was hydrocyanic acid gas. Since Cyanogas Calcium Cyanide contained only half as much cyanogen as sodium cyanide one ounce would evolve a quantity of hydrocyanic acid gas equivalent to only half a unit of liquified hydrocyanic acid, hence the dosage used was twice that shown on the liquid chart. For instance, in fumigating a tree which was 14 feet over and 16 feet around, 4 units of liquified hydrocyanic acid would be used, but on the basis of an equivalent amount a dosage of 8 ounces of Cyanogas Calcium Cyanide would be used. However, as a basis of the work in California, embracing hundreds of experiments covering a period of three years, it was found that an equivalent amount of Cyanogas Calcium Cyanide was not necessary, but that 75% of this amount of Cyanogas Calcium Cyanide would give a satisfactory kill of the insects. Hence in fumigating a tree of the size just mentioned it would only be necessary to use 6 ounces of Cyanogas Calcium Cyanide instead of 8 ounces. On this basis dosage Table I has been computed in terms of ounces of Cyanogas Calcium Cyanide "A" Dust. In calculating the dosages in this table, the California liquid schedule has been used as a standard since the highest dosages in the world are used in California.

Table II is for use in the humid coastal regions of New South Wales, where a lighter dose than that given in our regular dosage chart is advisable. This chart is based on Allen's No. 2 Table, published by the Department of Agriculture of New South Wales in 1923. Fractions have been eliminated since it is difficult for the fumigator to read them at night and few scales used in the field are accurately graduated in fractions of an ounce. Fractions less than half an ounce have been dropped, while those of half an ounce or over have been considered as one ounce.

TABLE I.—AMERICAN CYANAMID

STANDARD DOSAGE CHART FOR CYANOGAS CALCIUM CYANIDE FUMIGA

Distance Around (*In Fe*

DISTANCE OVER (*In Feet*)

					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48		5
20					7	8	9	9	9	9	9	10	11	11	11	11				0	
22					8	9	9	9	9	10	10	11	11	11	11	12	12	13		2	
24					9	9	9	9	10	11	11	11	12	12	12	13	13	14		4	
26								10	11	11	11	12	13	13	13	14	15	15	15	6	1
28									11	11	12	13	14	14	14	15	16	16	17	8	1
										30	32	34	36	38	40	42	44	46	48		5
30										12	13	14	15	15	16	17	18	18	19	0	2
32											14	15	16	17	18	18	20	20	21	2	2
34												15	17	18	20	20	21	21	22	4	2
36												17	18	20	21	21	22	23	24	6	2
38													19	21	22	23	24	25	26	8	2
															40	42	44	46	48		5
40																24	25	27	28	0	2
42																	27	28	30	2	3
44																		30	31	4	3
46																				6	3
48																				8	3
	12	14	16	18	20	22	24	26	28	30	32	34	36	38							5
10	3	3	4	4	5										10					0	3
12	4	4	5	6	6	6	6								12					2	
14	4	5	6	6	6	6	7	8							14					4	
16	6	6	6	6	7	7	7	8	8	8					16					6	
18	6	6	6	7	7	7	8	8	9	9	9	9	9		18					8	

TABLE I.—American Cyanamid Company

...art for CYANOGAS Calcium Cyanide Fumigation of Citrus Trees (*Ounces of CYANOGAS*)

Distance Around (*In Feet*)

4	26	28	30	32	34	36	38	40	42	44			
)	9	9	9	9	10	11	11	11	11				)
9	9	9	10	10	11	11	11	11	12	12	13		2
9	9	10	11	11	11	12	12	12	13	13	14		4
	10	11	11	11	12	13	13	13	14	15	15	15	[illegible]
		11	11	12	13	14	14	14	15	16	16	17	8

50	52	54	56	58	60	62	64	66	68	70	72	74			
															20
															22
															24
16															26
18															28

			30	32	34	36	38	40	42	44			
			12	13	14	15	15	16	17	18	18	19	)
				14	15	16	17	18	18	20	20	21	2
					15	17	18	20	20	21	21	22	4
					17	18	20	21	21	22	23	24	[illegible]
						19	21	22	23	24	25	26	8

50	52	54	56	58	60	62	64	66	68	70	72	74	7·	78	
20	20	21	21	23											30
21	22	23	23	24	25										32
22	24	25	26	26	27	28	29								34
25	26	27	27	28	29	30	30	31							36
27	28	29	30	30	31	31	32	33							38

								40	42	44			
									24	25	27	28	)
										27	28	30	
											30	31	
													)
													8

50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	
29	30	31	32	33	34	35	36	36	37	38					40
31	32	33	34	35	36	37	38	39	40	41	42				42
33	34	35	36	37	39	40	41	42	43	44	45	46			44
34	36	37	39	40	41	42	43	44	45	46	48	49	50		46
36	38	39	40	42	43	45	46	47	48	49	51	52	53	54	48

24	26	28	30	32	34	36	38	
								10
6								12
7	8							14
7	8	8	8					16
8	8	9	9	9	9	9		18

50	52	54	56	58	60	62	64	66	68	70	72	74			
38	39	40	42	44	45	47	48	49	51	52	53	54	55	57	50
			45	46	48	49	51	52	54	55	56	57	58	60	
				48	50	52	53	55	57	58	59	60	62	63	4
					52	54	56	58	60	61	62	63	64	66	56
					55	57	58	60	62	63	64	66	68	70	5·

TABLE II.—THE AMERICAN CYANAMID COMPANY

REDUCED DOSAGE CHART FOR *CYANOGAS* CALCIUM CYANIDE FUMIGATION OF CITRUS TREES (*Ounces*)

For Humid Coastal Regions, New South Wales, Australia

Diameter of Tree (Feet.)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		18	19	20	21	22	23	24	
7		¾	1	1	2	2	2	3	4	4	5					7								7
8			1	1	2	2	3	3	4	5	6	6	7	8		8								8
9				1	2	2	3	4	5	5	6	7	8	9	11	9								9
10					2	3	3	4	5	6	7	8	10	10	12	10	13							10
11						3	4	5	6	7	8	9	11	11	13	11	15	16						11
						8	9	10	11	12	13	14	15	16	17		18	19	20	21	22	23	24	
12						3	4	5	6	7	8	10	11	13	14	12	16	18	20	21	24	26	29	12
13								5	6	8	9	10	12	14	15	13	17	19	21	23	26	28	31	13
14								6	7	8	10	11	13	15	16	14	18	20	23	26	28	31	33	14
15									7	9	10	12	14	16	18	15	20	22	25	27	30	33	36	15
16									8	9	11	13	15	17	19	16	21	23	27	29	32	35	38	16
										12	13	14	15	16	17		18	19	20	21	22	23	24	
17										10	12	14	16	18	20	17	22	25	28	31	34	37	40	17
18										11	12	14	16	19	21	18	24	27	30	33	36	39	43	18
19										11	13	15	17	20	22	19	26	28	31	35	38	41	45	19
20										12	14	16	18	21	23	20	27	30	33	36	40	43	47	20
21													19	22	25	21	28	31	35	38	42	46	50	21
	3	4	5	6	7	8	9	10	11	12			15	16	17		18	19	20	21	22	23	24	
													20	23	26	22	29	33	36	40	44	48	52	22
													21	24	28	23	31	34	38	42	46	50	54	23
4	¾	¾	¾	1	1								22	25	29	24	32	36	39	43	48	52	57	24
5	¾	¾	¾	1	1									26	30	25	33	37	41	45	50	54	59	25
6	¾	¾	1	1	1	2	2	3	3	4				28	31	26	35	39	43	47	51	56	61	26

TABLE III. American Cyanamid Company

Standard Dosage Chart for CYANOGAS Calcium Cyanide Fumigation of Citrus Trees (*Grams of CYANOGAS*)

Distance Around (*In Feet*)

	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
20	198	226	255	255	255	255	255	283	311	311	311	311			
22	226	255	255	255	255	283	283	311	311	311	311	340	340	368	
24	255	255	255	255	283	311	311	311	340	340	340	368	368	396	
26				283	311	311	311	340	368	368	368	396	425	425	425
28					311	311	340	368	396	396	396	425	453	453	481
30						340	368	396	425	425	453	481	510	510	538
32							396	425	453	481	510	510	567	567	595
34								425	481	510	567	567	595	595	623
36								481	510	567	595	595	623	652	680
38									538	595	623	652	680	708	737
40												680	708	765	793
42													765	793	850
44														850	878
46															
48															

	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78
20															
22															
24															
26	453														
28	510														
30	567	567	595	595	623										
32	595	623	652	652	680	708									
34	623	680	708	737	737	765	793	822							
36	708	737	765	765	793	822	850	850	878						
38	765	793	822	850	850	878	878	907	935						
40	822	850	878	907	935	963	992	1020	1020	1048	1077				
42	878	907	935	963	992	1020	1048	1077	1105	1134	1162	1190			
44	935	963	992	1020	1048	1105	1134	1162	1190	1219	1247	1275	1304		
46	963	1020	1048	1105	1134	1162	1190	1219	1247	1275	1304	1360	1389	1417	
48	1020	1077	1105	1134	1190	1219	1275	1304	1332	1360	1389	1445	1474	1502	1530
50	1077	1105	1134	1190	1247	1275	1332	1360	1389	1445	1474	1502	1530	1559	1615
52				1275	1304	1360	1389	1445	1474	1530	1559	1587	1615	1644	1701
54					1360	1417	1474	1502	1559	1615	1644	1672	1701	1757	1786
56						1474	1530	1587	1644	1701	1729	1757	1786	1814	1871
58						1559	1615	1644	1701	1757	1786	1814	1871	1927	1984

	12	14	16	18	20	22	24	26	28	30	32	34	36	38
10	85	85	113	113	141									
12	113	113	141	170	170	170	170							
14	113	141	170	170	170	170	198	226						
16	170	170	170	170	198	198	198	226	226	226				
18	170	170	170	198	198	198	226	226	255	255	255	255	255	

TABLE IV.—American Cyanamid Company

Standard Dosage Chart for CYANOGAS Calcium Cyanide Fumigation of Citrus Trees (*Grams of CYANOGAS*)

Distance Around (*In Meters*)

6	6.6	7.2	7.8	8.4	9	9.6	10.2	10.8	11.4	12	12.6	13.2	13.8	14.4		15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4	
198	226	255	255	255	255	255	283	311	311	311	311				6																6
226	255	255	255	255	283	283	311	311	311	311	340	340	368		6.6																6.6
255	255	255	255	283	311	311	311	340	340	340	368	368	396		7.2																7.2
			283	311	311	311	340	368	368	368	396	425	425	425	7.8	453															7.8
				311	311	340	368	396	396	396	425	453	453	481	8.4	510															8.4
					9	9.6	10.2	10.8	11.4	12	12.6	13.2	13.8	14.4		15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4	
					340	368	396	425	425	453	481	510	510	538	9	567	567	595	595	623											9
						396	425	453	481	510	510	567	567	595	9.6	595	623	652	652	680	708										9.6
							425	481	510	567	567	595	595	623	10.2	623	680	708	737	737	765	793	822								10.2
							481	510	567	595	595	623	652	680	10.8	708	737	765	765	793	822	850	850	878							10.8
								538	595	623	652	680	708	737	11.4	765	793	822	850	850	878	878	907	935							11.4
										12	12.6	13.2	13.8	14.4		15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4	
											680	708	765	793	12	822	850	878	907	935	963	992	1020	1020	1048	1077					12
												765	793	850	12.6	878	907	935	963	992	1020	1048	1077	1105	1134	1162	1190				12.6
													850	878	13.2	935	963	992	1020	1048	1105	1134	1162	1190	1219	1247	1275	1304			13.2
															13.8	963	1020	1048	1105	1134	1162	1190	1219	1247	1275	1304	1360	1389	1417		13.8
															14.4	1020	1077	1105	1134	1190	1219	1275	1304	1332	1360	1389	1445	1474	1502	1530	14.4

	…2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.8	11.4	12				15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4	
3	…5	85	113	113	141									3		15	1077	1105	1134	1190	1247	1275	1332	1360	1389	1445	1474	1502	1530	1559	1615	15
3.6	…3	113	141	170	170	170	170							3.6		15.6				1275	1304	1360	1389	1445	1474	1530	1559	1587	1615	1644	1701	15.6
4.2	…3	141	170	170	170	170	198	226						4.2		16.2					1360	1417	1474	1502	1559	1615	1644	1672	1701	1757	1786	16.2
4.8	…0	170	170	170	198	198	198	226	226	226				4.8		16.8						1474	1530	1587	1644	1701	1729	1757	1786	1814	1871	16.8
5.4	…0	170	170	198	198	198	226	226	255	255	255	255	255	5.4		17.4						1559	1615	1644	1701	1757	1786	1814	1871	1927	1984	17.4

Since fumigation work in Egypt is based on dosages in terms of grams rather than ounces, Table III is given. The dosages are equivalents in grams of ounces as given in the regular Cyanogas Calcium Cyanide chart, Table I.

Table IV is for use in those countries, such as Spain, where the dosage is measured in grams and the tree dimensions in meters.

APPLICATION OF THE CALCIUM CYANIDE

In the early work Calcium Cyanide was either weighed out or measured out and the correct dosage placed in the duster and blown under the tent. A duster capable of measuring the exact dosage has been developed and is being used in Australia. Another machine which will measure the required dosage is now being developed in the United States.

EXPERIMENTAL WORK IN AUSTRALIA

Early in 1923 Professor H. J. Quayle went to Australia to conduct experimental work in that country. The fumigation with Cyanogas Calcium Cyanide dust was started in Australia at Leeton, New South Wales, on March 27, 1923. Leeton is one of the centers of the Murrumbidgee Irrigation Area, the largest irrigation scheme in the Commonwealth which will eventually include about a half million acres. This area is approximately 400 miles west of Sydney, New South Wales and a somewhat less distance north of Melbourne, Victoria. Fumigations on six different farms, embracing between 200 and 300 acres, established a dosage equivalent to 133% of our Cyanogas Calcium Cyanide schedule with usual length of exposure (45 to 50 min.). His temperature ranges were 55° to 80° and relative humidity ranged from 37% to 55%. The fumigations took place between 5.00 P. M. and 4.00 A. M. He experienced no commercial injury and a scale kill of 98% to 100%. The account of Professor Quayle's experiments, by Mr. K. C. McKeown, is taken from The Fruit World of Australasia, Vol. XXIV, No. 8, August 1923, p. 288, and is reset because of the arrangement in the original publication.

"Fumigation of Citrus Trees"

POTASSIUM CYANIDE METHOD SUPERSEDED

SUCCESSFUL TESTS WITH CALCIUM CYANIDE

By Keith C. McKeown

"The visit of Professor H. J. Quayle, Entomologist of the University of California, to Australia, is one which should prove of the greatest interest and importance to the fruit-growers of Australia, since he is introducing a new method of combating pests, and in particular Red Scale, which is one of the greatest pests the citrus orchardist has to fight," writes Mr. Keith C. McKeown.

"The method in use—fumigation with Calcium Cyanide—although new to Australia, has been in use for some years in California, where Professor Quayle evolved this new method of fumigation, and has carried out exhaustive experiments, which have been attended with notable success, not only in the control of scale insects, but also for the destruction of Aphis on Melons and Thrip on Onions; also as an efficient soil fumigant.

"Professor Quayle has spent four months on the Murrumbidgee (N.S.W.) Irrigation Areas during the last season, carrying out experimental work under local conditions, and I desire to express my appreciation and thanks to him for his courtesy in supplying me with full particulars and giving me every opportunity of seeing the work carried out and keeping track of his experiments.

"Fumigation With Calcium Cyanide Supersedes the old method, which is at present that generally in use, i.e., Potassium Cyanide, Water and Sulphuric Acid. The finely powdered Calcium Cyanide is produced in Canada at Niagara Falls by the American Cyanamid Co., of New York.

"The method of treatment is as follows:—The tent or sheet is placed over the tree as in the case of fumigation with Potassium Cyanide; there is not the necessity to place earth on the skirt of the tent. The ground under the trees should, however, be kept clean from weeds, etc., as these allow the gas to escape. The powdered Calcium Cyanide is applied by means of a small distributing machine; in the case of that

used during the tests, home made, consisting of a small Buffalo Blower mounted behind a hopper, in which a brush revolves to keep the powder from clogging, and fitted with a small "gate" by means of which the feed can be cut off. From this extends a length of rubber hose. The whole is mounted on a pair of light wheels, and can be drawn by hand from tree to tree. For convenience, a container for the stock of Calcium Cyanide and a small set of scales are carried on the truck. The Calcium Cyanide is weighed and the necessary charge placed in the hopper; the end of the hose held under the skirt of the tent and a few turns of the handle of the blower delivers the charge; the fine powder can be seen issuing from the end of the hose like grey smoke. The whole operation occupies only a few seconds. The duration of the exposure of the tree to the gas is the same as for fumigation with Potassium Cyanide 45 minutes. The expeditious handling is in strong contrast to the time occupied in measuring and mixing the materials for each tree inseparable from fumigation with Potassium Cyanide.

"The quantity of Calcium Cyanide used per tree is the same as for Potassium Cyanide, but there is no water or acid used; the Calcium Cyanide liberating Hydrocyanic Acid Gas on contact with the air. This, with Sulphuric Acid, is 7/6 per gallon, means a considerable saving alone; besides the fact that the Calcium Cyanide costs 8d. per lb. against 1/7 to 1/9 per lb. for Potassium Cyanide, giving for an average tree a cost for materials of 3d. as against 10d. in favour of the Calcium Cyanide. The above costs are calculated on the cost of the materials landed at Leeton, N.S.W. Another fact which must be taken into consideration is that there is no acid to burn the tents, and thus shorten the life of the most costly part of fumigation equipment.

"There is no doubt that fumigation with Calcium Cyanide can be worked satisfactorily under favourable weather conditions, but fumigation must be stopped on the break of the season. With trees fumigated in dry weather, there was a complete kill of the scale, with full dosage, with no injury to the tree, but the trees treated in wet weather, slight leaf drop, which, although not serious, showed that it was time to stop operations with the Calcium Cyanide and continue where necessary with the "pot method" with the Potassium Cyanide.

"Lemon trees proved particularly susceptible to injury if fumigated in damp weather.

"Calcium Cyanide is more restricted to favourable weather conditions than Potassium Cyanide. Its use is undoubtedly successful in dry districts under such conditions as prevail on the Murrumbidgee Irrigation Areas and many districts inland—where it will go far in solving Australia's fumigation problems.

"Further experiment is necessary to prove if it can be satisfactorily applied in the humid coastal districts, but even there in dry seasons it should be effective."

This method of citrus fumigation so appealed to the Water Conservation and Irrigation Commission of Leeton, New South Wales that arrangements were completed with Mr. F. F. Russell, a gentleman who had worked with Professor Quayle, to continue fumigation work in the Area on a contract basis. (See Figs. 4-1 and 5-1). During the season of 1924 a total of 4,163 orange trees and 400 lemon trees were successfully fumigated by Mr. Russell.

In January and February 1924, Professor W. J. Allen, Fruit Expert and Professor W. B. Stokes, Agricultural Department, New South Wales, conducted some experiments at Lismore in the humid coastal region of New South Wales. The reprint, giving the results of these tests is taken from Agricultural Gazette of New South Wales, Vol. XXXV, Pt. 8, Sept. 1924, p. 664. They used dosages of 33% to 100% of our standard Cyanogas Calcium Cyanide dosage chart. They obtained a satisfactory kill of red scale and full grown wax scale with the 33% dosage and of white lice by 66% dosage. They have not reported if smaller dosages will kill the white lice.

Professor S. A. Cock, Citriculturist of the Victorian Government, visited Leeton, New South Wales during the 1924 season and after carefully investigating the Cyanogas Calcium Cyanide dust method of fumigation as demonstrated in the commercial work, reported in favor of this method. New regulations were incorporated in the Vegetation Diseases Act which gave power to the orchard supervisors connected with this branch of the industry to inspect orchards and determine whether fumigation was necessary to ensure the proper control of pests. The Victorian Department of Agriculture provided experienced gangs of men with necessary equipment who fumigated orchards at a price based on the size of the trees. Professor Cock at the close of the 1925 season reported that his gangs had fumigated over 18,000

FIG. 4-1. Orange Tree Tented for Fumigation with Cyanogas Calcium Cyanide. Note marks on tent for determining distance over tree. Man using tape to measure distance around tree. Leeton, New South Wales, Australia.

FIG. 5-1.—Fumigation of Orange Trees, Leeton, New South Wales, Australia. Cyanogas Calcium Cyanide Dust is blown under tent. Material weighed accurately according to size of tree.

trees and that they planned to fumigate 36,000 trees the next season. He reported that in no case had there been serious injury to fruit or foliage of oranges, but that in one fumigation there was considerable burning and defoliation had resulted from fumigation of lemons. The dosage used in Victoria has been based on the use of one ounce to 100 cu. ft. of tent volume. At the close of the 1925 season over 23,000 citrus trees have been fumigated in Australia with Cyanogas Calcium Cyanide dust. All fumigations in Australia have been conducted in late afternoon or during the night.

EXPERIMENTAL WORK IN FLORIDA

In the Florida citrus district Cyanogas Calcium Cyanide dust came into prominence as an effective control measure for the citrus aphis (*Aphis spiraecola*) during the severe outbreak of 1924, Fig. 2-1. 100% kills of the aphis were obtained with a dose applied to tented trees for a short period (2 or 3 min.) Fig. 3-1. Fumigation, either by the pot method or with liquified hydrocyanic acid gas, has never been commercially successful in Florida. It would seem that several factors have militated against the adoption of fumigation as a general grove practice. The growers have never made a serious concerted effort to market their fruit in an absolutely scale-free condition because their market absorbed their product at a price which brought them a reasonable profit. Another factor, the high humidity with attendant heavy dews, produced a condition unfavorable to fumigation. The possibility of daylight fumigation seems never to have been thoroughly investigated. Consequently the growers, in general, relied to a considerable extent upon natural enemies in the form of parasitic insects and fungus diseases, or upon the use of oil sprays to hold the scale and mealy bug in check.

The experimental work in Florida was started in 1923 by Mr. S. W. Bromley who began a study of changes in temperature and relative humidity resulting from tenting a tree. Later Mr. R. W. Kelley and Mr. F. E. Todd conducted the work, already noted, on the control of the citrus aphis, and also preliminary experiments in the control of scale insects, white flies, and the rust mite by open air dusting. The work was started by using Cyanogas "A" Dust, but, in order to meet the need for an insecticide which would

effectively control the rust mite Cyanogas Citrus Dust was developed. This was accomplished by incorporating sulphur in the material since it was known that sulphur was effective against the mite. Cyanogas Citrus Dust was found to be effective not only for the mites but also their eggs.

It was soon found that open air dusting with Cyanogas Citrus Dust was no more effective in the control of scale insects and white flies than spraying. In order to obtain a more perfect control, experiments were conducted in the fumigation of trees under tents. The work was conducted in daylight to avoid the heavy dews and unfavorable night conditions. The first experiments were with heavy dosages for short periods of time but later work indicated the advantages of a lighter dosage for a longer period of time.

The following observations may be made on the basis of our experimental data. Daylight fumigation is practicable in Florida for oranges and grape fruit. No serious injury has resulted from fumigation at temperatures ranging from 70° to 90° Fahr. with the relative humidity ranging from 38 to 73 per cent. Fumigation should be administered, as far as possible, outside of the regular rainy season and when the tree has little or no young growth. The dosage used was that called for by our standard Cyanogas Dosage Chart but Cyanogas Citrus Dust was used instead of Cyanogas "A" Dust, the material normally used for citrus fumigation in other parts of the world. With a normal exposure of 45 minutes 98 to 100% control of citrus insects was obtained.

EXPERIMENTAL WORK IN SOUTH AFRICA

The fumigation of citrus trees with hydrocyanic acid gas has become an established practice in South Africa. Until the recent introduction of Cyanogas Calcium Cyanide, the fumigation of citrus trees had been done with sodium cyanide and acid or with liquified hydrocyanic acid distributed in glass ampules. During 1925, our Mr. R. O. Wahl has conducted an extensive series of experiments, having fumigated over 700 orange trees at the present time. Table V gives the summary of fifty of these experiments. This will serve as an indication of the type of citrus fumigation experiments which are being conducted in the various parts of the world.

It should be noted that in South Africa a much lighter dosage of sodium cyanide than that used in California is

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effective for scale control. The dosages given in Lounsbury's Table in the Journal of the Department of Agriculture, Union of South Africa, May, 1921 are relatively 25 per cent of the California schedule for small trees and gradually increase with the size of the tree until about 60 per cent of the California schedule is used.

Our experiments have shown that a dosage of Cyanogas which is 25 to 30 per cent of the regular Cyanogas Calcium Cyanide Dosage Chart will furnish an efficient kill of scale on small trees in South Africa. In April and May, daylight fumigation has been carried on successfully after 10:00 A.M. with no more injury to the tree than is normally experienced with other methods of hydrocyanic acid gas fumigation. In the bulletin cited above, Lounsbury makes the following statement regarding injury from cyanide fumigation. "The killing back of tender twigs for several inches and the dropping of some of the oldest leaves is to be expected; and when this damage does not occur it is advisable to increase the dosage in further work". From this statement it will be seen that leaf-fall and tip burning is not considered serious in South Africa. One should not infer from the above statement that a satisfactory kill of scale insects cannot be obtained without injury to the tree but that a certain amount of tip burning and leaf drop is not serious.

SAFE CONDITIONS FOR CYANOGAS CALCIUM CYANIDE DUST FUMIGATIONS

Most fumigations are conducted with a 45 minute exposure. In most countries fumigations are conducted at night time or in the late afternoon of a cloudy day. Calcium Cyanide may be used safely for the fumigation of orange and grape fruit trees under conditions which are safe for fumigations in which sodium cyanide or liquid hydrocyanic acid are used.

The order of susceptibility to injury appears to be Lemons, St. Michael's Orange, Valencia Orange, Naval Orange, Grape Fruit.

The fumigation of lemon trees is attended with some risk of injury the reason for which we have not as yet obtained a satisfactory explanation. In Australia lemon trees are frequently fumigated with Cyanogas Calcium Cyanide without serious injury.

TABLE V.—CITRUS FUMIGATION AT WHITE RIVER, TRANSVAAL, SOUTH AFRICA

SIZE OVER x AROUND	DOSAGE 25% CYANOGAS CHART	TIME ON.........OFF	EXPOSURE MINUTES	TEMP. DRY......WET	RELATIVE HUMIDITY	SCALE	INJURY	% KILL	REMARKS
14 x 17	1¼ ozs.	12.25 p.m.— 1.05 p.m.	40	68—57	50	Red	None	98%	Sky Cloudy
16 x 16	1½ "	3.40 p.m.— 4.20 "	40	67—57	53	do	None	99	" "
14 x 15	1¼ "	3.45 p.m.— 4.25 "	40	67—57	53	do	None	100	" "
17 x 16	1¾ "	4.25 p.m.— 5.10 "	45	62—55	64	do	None	100	" "
16 x 17	1½ "	4.30 p.m.— 5.15 "	45	62—55	64	do	None	100	" "
14 x 16	1¼ "	5.30 p.m.— 6.15 "	45	59—54	72	do	None	100	" "
14 x 16	1¼ "	5.35 p.m.— 6.20 "	45	59—54	72	do	None	100	" "
16 x 17	1½ "	6.20 p.m.— 7.05 "	45	58—54	71	do	None	100	Very Cloudy
14 x 16	1¼ "	6.25 p.m.— 7.10 "	45	58—54	71	do	None	100	" "
13 x 15	1¼ "	7.10 p.m.— 7.55 "	45	56—53	82	do	None	100	" "
14 x 15	1¼ "	7.20 p.m.— 8.05 "	45	56—53	82	do	None	100	" "
12 x 12	1¼ "	8.05 p.m.— 8.50 "	45	55—52	82	do	None	100	" "
13 x 15	1¼ "	8.15 p.m.— 9.00 "	45	55—52	82	do	None	100	Fairly Cloudy
14 x 14	1¼ "	9.00 p.m.— 9.45 "	45	52—51	94	do	None	100	" "
13 x 14	1¼ "	9.10 p.m.— 9.55 "	45	52—51	94	do	None	100	Sky Clear
11 x 10	1 "	9.50 p.m.—10.35 "	45	51—50	94	do	None	100	" "
12 x 12	1¼ "	10.00 p.m.—10.45 "	45	51—50	94	do	None	100	" "
15 x 15	1¼ "	10.45 a.m.—11.25 a.m.	40	66—56	53	do	Slight	100	" "
15 x 17	1½ "	10.50 a.m.—11.30 "	40	66—56	53	do	Slight	100	" "
15 x 13	1¼ "	11.30 p.m.—12.10 p.m.	40	65—55	53	do	Slight	100	Fairly Cloudy
14 x 14	1¼ "	11.35 a.m.—12.15 "	40	65—55	53	do	Slight	100	" "
16 x 15	1½ "	12.15 p.m.—12.55 "	40	68—57	50	do	Slight	100	Fair Breeze
15 x 18	1½ "	12.20 p.m.— 1.00 "	40	68—57	50	Red and Circ. Purple	Slight Leaf Fall Young Shoot Burnt	100	" "
16 x 17	1½ "	2.40 p.m.— 3.20 "	40	70—57	44	Red	Slight	100	" "
15 x 15	1¼ "	2.45 p.m.— 3.25 "	40	70—57	44	do	Slight	100	" "
12 x 14	1¼ "	3.25 p.m.— 4.05 "	40	67—56	49	do	Slight	100	Sky Clear
15 x 15	1¼ "	10.40 a.m.—11.20 a.m.	40	64—56	61	do	Moderate	100	" "
10 x 10	1 "	10.45 a.m.—11.25 "	40	64—56	61	do	Slight	100	" "
10 x 9	1 "	11.25 a.m.—12.15 p.m.	50	66—56	53	do	Slight	100	" "
9 x 11	1 "	11.30 a.m.—12.20 "	50	66—56	53	do	Slight	100	" "
13 x 13	1¼ "	12.20 p.m.— 1.00 "	40	69—57	47	do	Fairly Hvy. (tree in poor condition)	100	Strong Breeze
15 x 16	1¼ "	12.25 p.m.— 1.05 "	40	69—57	47	do	Fairly Hvy.	100	" "
16 x 17	1½ "	1.15 p.m.— 1.55 "	40	68—57	50	do	Moderate	100	" "
14 x 14	1¼ "	1.20 p.m.— 2.00 "	40	68—57	50	do	Moderate	100	" "
14 x 13	1¼ "	2.10 p.m.— 2.50 "	40	68—57	50	do	Slight	100	Soft Breeze
14 x 14	1¼ "	2.15 p.m.— 2.55 "	40	68—57	50	do	Slight	100	" "
12 x 11	1 "	3.00 p.m.— 3.40 "	40	68—57	50	do	Slight	100	" "
11 x 10	1 "	3.05 p.m.— 3.45 "	40	68—57	50	do	Slight	100	" "
10 x 11	1 "	3.45 p.m.— 4.25 "	40	66—56	53	do	Slight	100	" "
13 x 14	1¼ "	3.50 p.m.— 4.30 "	40	66—56	53	do	Slight	100	" "
17 x 17	1¾ "	4.35 p.m.— 5.15 "	40	64—55	56	do	Slight	100	" "
15 x 15	1¼ "	4.40 p.m.— 5.20 "	40	64—55	56	do	Slight	100	" "
14 x 15	1¼ "	5.20 p.m.— 6.00 "	40	60—54	68	do	Slight	100	" "
8 x 11	1 "	5.25 p.m.— 6.05 "	40	60—54	68	do	Slight	100	" "
13 x 13	1¼ "	10.25 a.m.—11.05 a.m.	40	71—54	30	do	Slight	100	Sky Clear
14 x 15	1¼ "	10.30 a.m.—11.10 "	40	71—54	30	do	Slight	100	Strong Breeze
13 x 15	1¼ "	11.10 a.m.—11.50 "	40	72—55	31	do	Slight	100	" "
14 x 13	1¼ "	11.15 a.m.—11.55 "	40	72—55	31	do	Slight	100	" "
14 x 15	1¼ "	11.55 a.m.—12.35 p.m.	40	73—55	29	do	Slight	100	
15 x 16	1½ "	12 noon—12.45 p.m.	45	73—55	29	do	Moderate	100	Leaves of Trees were Mottled
12 x 13	1¼ "	12.45 p.m.— 1.30 "	45	74—56	29	do	Moderate	100	Soft Breeze
13 x 14	1¼ "	12.55 p.m.— 1.40 "	45	74—56	29	do	Slight	100	" "

NOTE:—Red Scale—*Chrysomphalus aurantii* Mask.
Circular Purple Scale—*Chrysomphalus aonidum* L.

ADVANTAGES OF CYANOGAS DUST FUMIGATION

1. Simplicity of application.
2. Effective — Gives practically 100% kill of scale and other citrus pests.
3. Does away with use of acid with consequent longer life to tents.
4. Can be used under practically same conditions as old methods as far as safety to tree is concerned.
5. Greater safety in handling.

TABLE VI

A list of citrus insects which have been controlled in various countries with Cyanogas Calcium Cyanide.

Citrus Insects		California	Florida	Texas	Australia	S. Africa
California Red Scale	*Chrysomphalus aurantii* Mask.	x		x	x	x
Florida Red Scale or Circular Purple Scale	*Chrysomphalus aonidum* Linn.		x	x		x
Yellow Scale	*Chrysomphalus citrinus* Coq.	x				
Purple Scale	*Lepidosaphes beckii* Newm.	x	x	x		
Long Scale	*Lepidosaphes gloverii* Pack.		x			
Black Scale	*Saissetia oleae* Bern.	x				
Brown Scale	*Coccus hesperidum* Linn.		x	x	x	
Wax Scale	*Ceroplastes floridensis* Com.		x		x	
Cottony Cushion Scale	*Icerya purchasi* Mask.		x			
Citrus White Fly	*Aleyrodes* sp.		x			
Rust Mite	*Eriophyes oleivorus* Ash.		x			
White Louse	*Pseudococcus* sp.				x	
Citrus Aphis	*Aphis spiraecola* Patch.		x			

Calcium Cyanide for Citrus Fumigation.

A Comparison with Sodium Cyanide.

W. J. ALLEN and W. B. STOKES.

In the *Agricultural Gazette* for December, 1923, some trials were reported that had been conducted on Murrumbidgee Irrigation Area with calcium cyanide as a fumigant for citrus trees, and mentioned that experiments would be conducted in some coastal district where the humidity of the atmosphere—of particular importance in fumigation with calcium cyanide—is greater.

It is the purpose of this article to set out the results of experiments conducted in the orchard of Mr. J. R. Chapman at Lismore in January and February, 1924, to compare the calcium cyanide dust treatment with the sodium cyanide method, and to determine the effects of the calcium cyanide under conditions of high relative humidity.

To determine the relative humidity a dry and wet bulb thermometer was used. Varying dosages of calcium cyanide were given, as it was thought that those recommended appeared too high. For the sodium cyanide treatment the revised table of 1903 was used without any variation of dosages. Owl's Fumigation Chart, Azusa, California, was used as a basis with the calcium cyanide dust method.

Certain instructions, as follows, are given in connection with the use of these calcium cyanide dosages:—

In calcium cyanide dust fumigation the tree is covered as for ordinary fumigation, and the dosages estimated in the same way. The distance over the tree from ground to ground, and the distance round the tree at a height of 3 feet are determined and referred to the attached chart. For example, a tree measuring 32 feet over and 36 feet round requires a dosage of 10 oz. as shown on the chart. For a full regular dosage of calcium cyanide, multiply the chart number by 2. Thus the tree whose dimensions were just mentioned would require 20 oz. of calcium cyanide.

Experiments to date have shown that a 75 per cent. dosage will be sufficient. The above dose (20 oz.) is considered 100 per cent. dosage, hence a 75 per cent. dosage will be 75 per cent. 20 oz. = 15 oz. Good results have been obtained with 50 per cent. dosages, but the results are not constant enough to be recommended. The required quantity of calcium cyanide is then weighed out, put into the duster, and blown under the tent. The dust may be applied in the same way using a dust machine, in which a measuring device has been incorporated.

The dust should be uniformly distributed throughout the tent, and this may be accomplished by discharging it vertically upwards from the ground near the centre of the tented area. The tent should be left on the tree for the usual time following the dust application, namely 45 minutes to one hour.

Further instructions given are:—

Many experiments in California have shown that there is a direct relationship between the relative humidity and the injury to the trees. In daylight fumigation the relative humidity at the time of fumigation should be 40 per cent. or less. This is particularly true of work at high temperatures. Late in the afternoon as the temperature drops the relative humidity may be somewhat higher, say 45 per cent. to 50 per cent. After dark the relative humidity may be as much as 70 per cent. to 75 per cent. Some experiments at 80 per cent. were without injury, but are really in the danger zone. Results tend to

show that the trees should be dry at the time of fumigation, but may become wet with dew or rain later providing the relative humidity at the time of fumigation is correct. In general, treatment is safe on dry nights or days with low relative humidity, but the middle of the day with its high temperatures should be avoided, unless the relative humidity is very low—that is, below 40 per cent.

Experience in this State has shown that daylight fumigation, except in late afternoon, is within the danger zone, especially in strong sunlight or high temperatures.

The results of the tests carried out at Mr. Chapman's orchards are summarised in the appended table, which shows the size of tree, time, humidity, calcium cyanide dose percentage, date, dosages of calcium cyanide and of sodium cyanide, and cost of each for same-sized tree.

COMPARATIVE COSTS of Fumigation with Calcium Cyanide and Sodium Cyanide.

Date.	Time of day of Treatment.	Relative Humidity.		Size of Trees.				Dosages and Cost of Material.					
								Calcium Cyanide.			Sodium Cyanide.		
		Inside Tent.	Outside Tent.	Height.	Diameter.	Round.	Over.	Dosage.	Dose per centage.	Cost.	Sulphuric Acid.	Sodium Cyanide.	Cost.
1924.	p.m.	per cent.	per cent.	ft.	ft.	ft.	ft.	oz.	per cent.	pence.	oz.	oz.	pence.
29 January	4·55	73	48	..	..	21	20	5	50	4·8	..	..	
	5·55		54	..		28	22	9	75	8·7	..	..	
	6·40		55	11	10	28	22	6	50	5·8	4	3⅓	3·7
6 February	6·35	95	81	7½	7	20	18	7½	75	7·2	2	2	2
	7·35	100	85	7	8	22	17	4	40	3·8	2	2	2
	8.40	100	85	7	9	25	18	3⅓	33⅓	3·1	2½	2½	2·5
	9·45	100	90	7½	6	17	16	4	50	3·8	1½	1½	1·5
8 February	6·30	90	80	8	10	29	23	9	75	8·7	3½	3½	3·2
	6·30	90	80	9	8	..	..	..			2½	2½	2·5
	8·0	89	100	8	10	23	22	5	40	4·8	3½	3¼	3·2
	8·0	89	100	10	8	..	..	..	..	..	3	2⅔	2·7
	9.10	89	100	7	7	18	15	3	33⅓	2·9	1½	1⅓	1·5
	9·10	89	100	7	7	..	..	..	..	..	1½	1½	1·5

It will be noticed that humidity up to 100 per cent. was experienced during the test, and in some instances the trees were wet with dew. Damage was done by both methods to a slight extent, that is, young growth was killed and leaves fell from the trees. In one or two instances the fall of leaves was more than should have taken place, and one 75 per cent. dosage of calcium cyanide burnt several fruit. It must be remembered, however, that these tests were carried out under conditions that are considered to be severe (humidity up to 100 per cent. and the trees at times wet with dew). No serious damage resulted; the trees made new growth almost immediately after treatment, and the foliage is now as dense as one would desire. This is in marked contrast to many citrus trees in this district that have been sprayed with oils.

The principle scale insects on the trees treated were red scale and white louse. There were a few brown olive and wax scale, but not sufficient to warrant definite conclusions being drawn as to the kill that would take

place with these two last-mentioned scale insects. Both methods of treatment gave equally good results. Calcium cyanide killed red scale with all dosages given, namely, from 33⅓ per cent. to 75 per cent. dosages, and white lice were definitely killed with a 50 per cent. dosage. It is not known from these tests whether white lice can be killed with a smaller dosage. Sodium cyanide killed all red scale and white lice at the dosages set out in the departmental revised table.

Since the experiment described was carried out, arrangements were made with two other orchardists in the Gosford district to test the calcium cyanide method of fumigation. The work on one of the orchards was carried out during very humid weather, dews and fogs occurring almost every night, and rain fell at frequent intervals. Considerable damage was done, but in all probability was due more to over-dosages than to humidity. One section of trees was done during the afternoon of a dull day, with the result that practically all the leaves came off and many of the fruit. On the other orchard a start was made with a 25 per cent. dosage of calcium cyanide on one row of Emperor Mandarins, changing on the next row to 33⅓ per cent. dosage, and thereafter to a 40 per cent. dosage. These trees were examined recently, and it was found that red scale and odd fully-grown wax scale had been killed with a 25 per cent. dosage.

These tests have thus shown that calcium cyanide may be used in the humid coastal areas, provided care is exercised not to do the work during times of high relative humidity, or when the trees are wet, or during daytime. The safety zone of sodium cyanide fumigation is also generally controlled by these conditions.

The cost of the materials used in these tests, and set out in the table, is based on quotations obtained in Sydney on 22nd July, 1924, as follows:—Calcium cyanide, £6 10s. per 100 lb., or approximately 1s. 3½d. per lb.; sodium cyanide, 1s. 2d. per lb. in hundredweight lots, and sulphuric acid 16s. 6d. per cwt. or approximately 2d. per lb.

Reprint from The Florida Grower, February 27, 1926, p. 9

Fumigation of Citrus Trees in Florida

Although the Cost is Greater than that of Spraying, the Increased Efficiency Resulting from This Method of Application May Make it Desirable.

By Prof. J. R. Watson

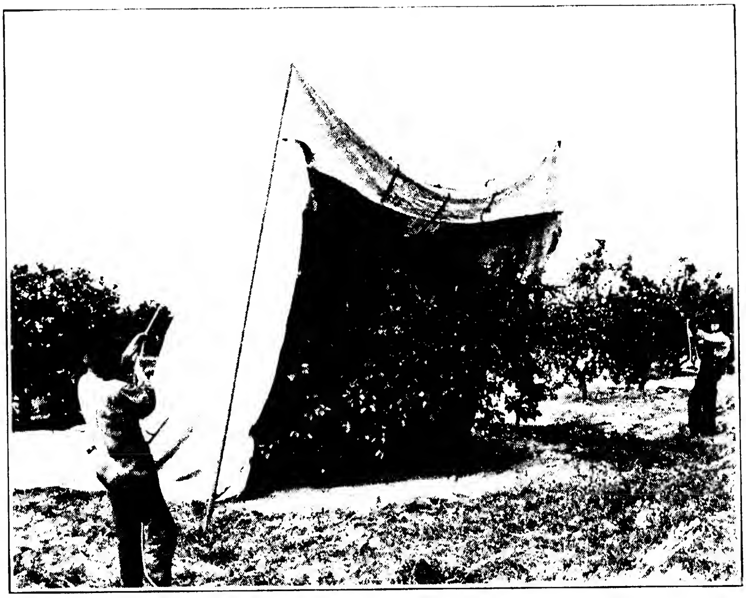
Entomologist, Florida Agricultural Experiment Station

Fumigation of citrus trees with hydrocyanic acid gas as a means of controlling insect pests has been tried many times in Florida, but has never been extensively used by growers. Different methods of generating the gas have been used. The latest is by the use of calcium cyanide, a black dust which by absorbing moisture from the air or soil, generates the gas. This method seems to eliminate some of the objectionable features of the older methods which were responsible for the abandonment of fumigation in Florida.

During the past year the writer has been checking up the kill secured by the American Cyanamid Company in various groves in Florida under the supervision of R. W. Kelley.

METHOD OF DUST APPLICATION

In the present work the trees are covered with one of the regular California fumigation tents. These are octagonal sheets of canvas, provided with rings on one side into which a spike on the top of a pole is fitted, then with ropes attached to the pole the tent is drawn over the tree. The tents are calibrated in two directions in such a way that one can read off directly the circumference and the distance over the tree. These readings determine the dosage to be used. For this purpose dosage tables are employed. The dosage used in most of these experiments is three-fourths that of the California recommendations. It is recommended that the dust be directed on to the ground, as when it is directed into the tree there is apt to be too heavy a layer deposited on certain twigs and leaves. Of course when directed onto the ground there will be a fine cloud of the dust that will rise all through the tent and settle on the foliage in a more or less uniformly distributed coating. The tents are left over the trees for 45 minutes. In order to keep a crew busy moving tents and dusting trees it is necessary to have ten or a dozen tents. The dosage must be accurately measured, not guessed at. The American Cyanamid Company has been working on a dust gun which will



Pulling Tents over Trees is Comparatively Simple Operation

measure the dust before it is pumped under the tents. If there is any considerable wind it is necessary to throw a few shovelfuls of dirt on the edges of the tent resting on the ground to hold it in place and prevent the loss of the fumes.

Naturally the earlier experiments were not as satisfactory as later ones, due largely to inaccurate methods of measuring the dust.

The dust used in most of this work is the so-called "citrus dust." This is calcium cyanide to which sulphur has been added with the idea of getting a better control of rust mites and red spiders.

TREES MUST BE ABSOLUTELY DRY

The chief trouble with the older methods of fumigating citrus trees, such as the generation of the gas by means of pouring sulphuric acid on sodium cyanide—the "pot method"—and the use of the "cyanafumer"—tried out in Florida a number of years ago—was that it could be used only at night and during a few weeks in the winter time. The calcium cyanide has been used during the past year in practically all months except the rainy season. It has been used when the temperature was as high as 95 degrees and the relative hum-

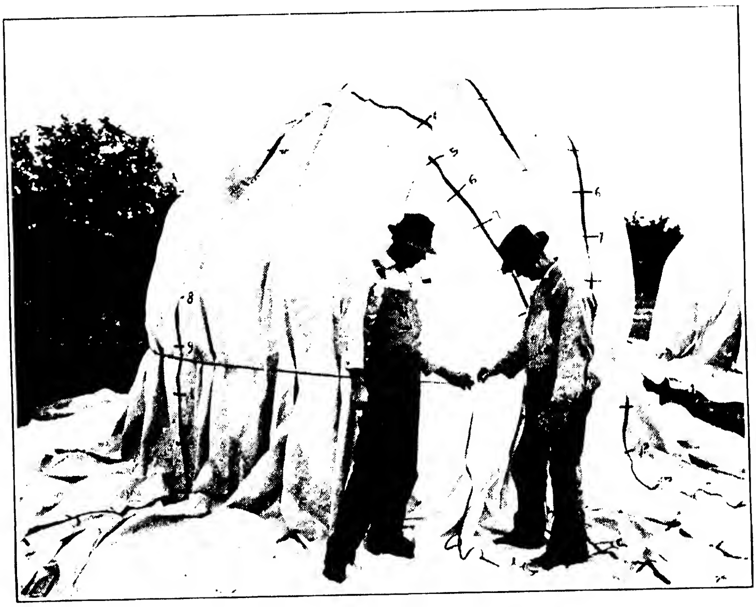
idity as high as 75 per cent. Under these severe conditions there were some fall of leaves, but seldom if ever more serious than that which would have followed spraying under these atmospheric conditions. The work has all been done in the day time. The one condition which must be fulfilled in order to avoid severe burning is that the TREES BE ABSOLUTELY DRY. The work must not be started in the morning until the dew has evaporated or after a shower until after the trees have become dry again. If these precautions are taken and the dosage is accurately measured and evenly distributed, the injury to foliage and fruit seems to be no greater than that of spraying under similar conditions. Leaves which have been affected with "greasy spot" or "black melanose" seem to be the first to drop as a result of the dusting.

Although the hydrocyanic acid gas kills practically all citrus insect pests with the exception of mealy bugs, our work has been mostly with purple scale, Florida red scale, and rust mites. Our rather limited observations on whitefly would indicate that anything which will kill the purple scale will also kill the whitefly. There has not been a great deal of whitefly on the trees on which we have been working.

HEAVY KILL ON PURPLE SCALE

The average kill of purple scale for the last few weeks has been 95 per cent. On most trees it is much better than this, but in checking up behind the fumigating outfit we occasionally run across a tree with a much poorer kill than others. This brings the average down to 95 per cent. It is probable that the poorer kills on these occasional trees are due to the trees not receiving the proper dosage. In the earlier work considerable difficulty was experienced in getting a machine which would quickly and accurately measure the dosage. This problem seems likely to be solved. We expect the counts on future fumigations to show fewer of these trees with a poor kill. On most trees the only purple scales which escape are those which are under something. Purple scale has a tendency to get under other purple scales, under spider webs and into colonies of the woolly whitefly. In these situations it is difficult to reach the bottom scale either with fumigation or with sprays. In most cases, even in such protected situations, only the eggs escape the fumigation. The above kill is of course very satisfactory indeed and much better than is obtained in ordinary spraying operations. But with further work it would seem possible to get even a higher percentage of purple scale.

The average kill on Florida red scale has been 98 per cent. This is even more satisfactory than in the case of the purple scale. The reason for this is that the Florida red scale seldom gets under another scale and does not have the same tendency to get under webs and other protection that the purple scale has. The Florida red scale is a very difficult one to kill with ordinary sprays; and the ease with which it is killed in this fumigation process would seem to be one of the most promising applications of the use of hydrocyanic acid gas.



Measuring a Tree to Determine Amount of Dust Needed

RUST MITES EASILY CLEANED UP

Fumigation seems to give an unusually good cleanup of rust mites. In one grove, fumigated in September, rust mites could be found a month later on only one fumigated tree, while they were abundant on unfumigated trees in the same grove. Two months after fumigation they had commenced

This Hand-power Duster Measures Dust to a Fraction of an Ounce

to reappear on the fumigated trees, but even then were not as abundant as on unfumigated trees around them. In this experiment the fumigated trees were surrounded on all sides with trees which were not fumigated. If a whole grove was fumigated the reappearance of the rust mites would probably be even greater delayed. Just how long one fumigation will keep rust mites under control is a question for the future to decide, but at the present time it looks as if this might be considerably longer than with spraying or ordinary dusting with sulphur.

The cost of fumigation is of course considerably greater than that of spraying. But it is quite possible and even probable that fumigation will not need to be repeated as spraying or dusting. If further experiments with this method of controlling pests confirm this anticipation, fumigation may compare very favorably with spraying as far as cost is concerned. It is certainly more thorough, especially on Florida red scale, and seems to be as safe.

Olive Fumigation With Cyanogas Calcium Cyanide

Although the fumigation of citrus trees with hydrocyanic acid has become a well-known method of insect pest control throughout the world, the fact that the fumigation of olive trees has been a commercial practice in certain parts of Europe is not so generally known.

The original method of olive fumigation was by means of hydrocyanic acid gas derived from the reaction of potassium and later sodium cyanide with sulphuric acid and water. The adaptation of Cyanogas Calcium Cyanide to this work has been recently accomplished.

We are here publishing Mr. F. E. Todd's original article covering his investigations on this subject in Spain, and are also reproducing from the Boletin de la Estacion de Patologia Vegetal, Año. I Núm. 2., pages 55-64, Abril de 1926, Senor Miguel Benlloch's account of his experiments on Olive Fumigation with Cyanogas Calcium Cyanide, with an English translation of the same.

THE CYANOGAS CALCIUM CYANIDE METHOD OF OLIVE TREE FUMIGATION IN SPAIN

By F. E. Todd, Entomologist
American Cyanamid Sales Company

Introduction

Olive tree fumigation with hydrocyanic acid gas has been practised in Spain since 1912, when Prof. Leandro Navarro of the Estacion de Patologia Vegetal in Madrid, determined, after many years of research with sprays and other methods, that the only effective control measure for the Olive Thrips, *Phloeothrips oleae* Costa., was tent fumigation with hydrocyanic acid gas following the standard method practiced on citrus trees. He discovered that a satisfactory control could be obtained by using as low a dosage as 14% of the Standard Cyanide Dosage table then in use in Spain for the fumigation of citrus trees. He also found that daylight fumigation could be safely practiced, and determined the best season for operation, viz.—October to March. In practice, however, fumigators found that more lasting results could be obtained by increasing the dosage to 20% of the original citrus dosage table.

The principal insect pests of the olive in Europe are:

(1)	Olive Thrips	. . .	*Phloeothrips oleae* Costa.
(2)	Olive Psylla	. . .	*Euphyllura olivina* Costa.
(3)	White Olive Scale	.	*Aspidiotus hederae* Vallot
(4)	Black Olive Scale	.	*Saissetia oleae* Bern.
(5)	Olive Twig Borer	.	*Phloeotribus scarabaeoides* Bern.
(6)	Olive Twig Moth	.	*Prays oleaellus* F.
(7)	Olive Fly	. . . .	*Dacus oleae* Rossi.

Of these the most important by far in the regions favorable to its development is the Olive Thrips. Fumigation was directed primarily against this insect but in practice it was found also to be the most effective control measure for the Olive Psylla, the Twig-borer, and the Black and the White Olive Scales, since the most vulnerable stages of these insects occur during the fumigation season. The Olive Thrips, the Psylla, and the Twig-borer hibernate as adults from October to March, and the most easily controlled stages of the black scale also occur during this period. Hence it will be seen that the fumigation season was rightly placed; not only in respect to the thrips, but also in relation to the other major olive pests. For the scale, particularly the black scale, however, the dosage will probably have to be increased.

The Importance of the Olive Thrips (*Phloeothrips oleae*)

The large black Olive Thrips is the most serious pest of the olive in locations which are favorable to its normal development, those most favored being the higher slopes of mountains. It is reported to have caused the abandonment of extensive plantings in France and Italy, and has forced the Spanish growers to solve the problem of its control or do likewise.

The Olive Thrips is a member of the Tubulifera sub-order of the Thysanoptera, its complete life cycle being spent on the olive tree. The female produces about thirty eggs, and there are three generations a year. The adult hibernates in a more or less active state, depending on the temperature, within the abandoned burrows of the Olive Twig-borer or within the tightly curled leaves. Since the adult is not a flying insect, its wings being too weak, and since it is also a sluggish walker, it must therefore depend upon the wind and other natural agencies for its spread.

Both the nymphal and adult stages of this insect feed on the leaves and fruit of the olive tree. The injury to the leaves consists of a curling and dwarfing, rendering them useless as food producing units, as well as resulting in a stunting of the twigs, and a lessening of the number of fruit buds. The injury to the fruit consists of stunting, distorting, and general weakening which causes an abnormally large drop during August. A general devitalized condition of the tree results and experience has shown that a serious cut in production and quality of the oil is occasioned where infestations are severe. The death of the tree may occur in extreme cases.

Fig. 6-1. Fruit Injury Caused by the Olive Thrips. Note Shrivelled Appearance of Olive on Right.

Benefits of Olive Fumigation

The fumigation of olives for the control of the Olive Thrips has been sufficiently tested during the past twelve years to convince the Spanish growers of its value. It is generally claimed that the yields the year following fumigation will be doubled or tripled and that the benefits may be distinguished over the following three to five years.

My inspections convinced me that one fumigation would be effective over three years, and I believe if fumigation were more widely practiced more lasting effects could be expected, since reinfestation takes place slowly. It may be expected therefore that one fumigation will greatly increase the crop of fruit for the following three years, and thus distribute its cost over that period.

The Cyanogas Method

The advent of Cyanogas Calcium Cyanide which, due to its safety and greater ease of application, has made nearly obsolete in many places the older methods of generating hydrocyanic acid gas for fumigation purposes was eagerly received by Prof. Miguel Benlloch, Director, Estacion de Patologia Vegetal, Madrid, who with the writer performed extensive tests to prove the reliability and efficacy of Cyanogas for the fumigation of olives.

The experiments performed in Mora de Toledo, Spain, from October 1925 to March 1926 are dealt with in the remainder of this article.

Method of Checking the Experiments

In working out of a method of checking the experiments the following observations were first made:

(1) Thrips killed by fumigation fail to fall from the tree unless it is shaken, whereupon they fall easily.
(2) It is possible to shake the live thrips from a tree.
(3) All recovery from fumigation will have taken place within 24 hours after the fumigation.
(4) Live thrips may be easily distinguished since they move when prodded.

With this information at hand it was easy to determine the percentage of kill to a fairly accurate degree by shaking the tree over a white cloth and counting the dead and live thrips coming down.

Method of Application

Since Cyanogas Calcium Cyanide depends upon atmospheric moisture for the release of hydrocyanic acid gas, it would therefore be expected that the better the distribution of the dust in the air the quicker and more thorough the reaction. This would result in a more thorough distribution of the gas within the tent, and a higher kill would be obtained due to the greater likehood of contact with the thrips. On the other hand a thorough distribution of the dust involves more labor and a more complicated equipment.

Experiments were made to determine what differences, if any, there might be between a direct and an indirect method of application of the dust. A direct application was made by thoroughly dusting the crown of the tree, while an indirect application was made by blowing the dust toward the ground.

These experiments indicated that a saving of 30% in dosage could be made by using a direct application. The results of these tests are shown in the accompanying table.

Dosage % ACCO. Table	% Kill* Direct Application	Indirect Application
7.5	22	
10	41	53
15	88	85
20	98	90
30	99	98

*Each % represents the average of 4 trees.

The weather conditions during these tests were uniform. Applications were made by means of a Niagara Junior Hand Duster.

The direct application was made by raising a side of the tent and directing the nozzle in such a way as to dust thoroughly the leafly top of the tree. This served to place the dust in intimate contact with the insects and even effected the entrance of some of the dust into the borer holes. With the low dosages used in this work good distribution is a very important factor.

In the experiments, a Niagara Junior Hand Duster and a FQSA duster, made by Fumigadores Quimicos of Valencia, Spain were used. The latter had a practical self-measuring device which accurately measured 24 grams per unit. Both dusters were of the fan type and gave equally successful results.

Determination of Dosage

In the determination of the dosages of Cyanogas Calcium Cyanide necessary to produce kills of approximately 100% of the Olive Thrips, several hundred trees were fumigated. Experience has shown the growers that where kills of approximately 100% are made, the benefits of fumigation will be felt over a period of three to five years, as previously mentioned; for this reason they are particular that the kill shall not fall below this mark.

In all of this work care was taken to make the applications direct, to use exposures of one hour, to work at temperatures above 40 degrees F. and to use tents free from holes.

The results of these experiments showed conclusively that under the ordinary fumigation weather a dosage of 20% of the "Standard Dosage Table for Citrus Trees" will produce the

desired results. In the warmer weather of late spring the same results can be obtained with about 16% of this table. Commercial tests involving the fumigation of more than two thousand trees have served to confirm the perfect results that can be obtained with the 20% dosage. The accompanying table (Table V) based on this dosage was accordingly adopted.

Tabulated below are representative results obtained with Cyanogas Calcium Cyanide as well as a comparison of the results obtained with gas generated from sodium cyanide by the pot method, using the recommended proportion of NaCN, H_2SO_4, and H_2O of 1-1½-2. From these experiments it will be seen that is is necessary to use about ¼ more Cyanogas by weight to produce results equal to those obtained with NaCN.

Sodium Cyanide		Cyanogas	
% Dosage (ACCO Table)	% Kill	% Dosage (ACCO Table)	% Kill
8½	65	9	67
10	92	14	87
12	97	17	97
14	99	18	100
15	97	21	99
16	99	22	98
17	100	23	100
21	99	24	100
22	100	25	99
		27	100
		28	99
		29	99
		35	100

Fumigations conducted under ordinary fumigation weather (Temperature above 40° F.)

Determination of Length of Exposure

Olive fumigations performed with sodium cyanide are given an exposure of one hour. It was first thought that this exposure might be reduced with a Cyanogas fumigation. Experiments were performed to determine this point but it was found that the most satisfactory results could be obtained with economical dosages if a one hour exposure were used.

TABLE V—American Cyanamid Sales Company

Olive Fumigation Chart for Spain (20% of Standard Citrus Table No. IV)

Cyanogas Calcium Cyanide "A" Dust (*Grams*)

Distance Around (*Meters*)

Distance Over Tree (*In Meters*)

	6	6.6	7.2	7.8	8.4	9	9.6	10.2	10.8	11.4	12	12.6	13.2	13.8	14.4
6	39	45	51	51	51	51	51	57	62	62	62	62			
6.6	45	51	51	51	51	57	57	62	62	62	62	68	68	74	
7.2	51	51	51	51	57	62	62	62	68	68	68	74	74	79	
7.8				57	62	62	62	68	74	74	74	79	85	85	85
8.4					62	62	68	74	79	79	79	85	91	91	96

	15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4
6															
6.6															
7.2															
7.8	90														
8.4	102														

	9	9.6	10.2	10.8	11.4	12	12.6	13.2	13.8	14.4
9	68	74	79	85	85	91	96	102	102	108
9.6		79	85	91	96	102	102	113	113	119
10.2			85	96	102	113	113	119	119	125
10.8			96	102	113	119	119	125	130	136
11.4				108	119	125	130	136	142	147

	15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4
9	113	113	119	119	125										
9.6	119	125	130	130	136	142									
10.2	125	136	142	147	147	153	159	164							
10.8	142	147	153	153	159	164	170	170	176						
11.4	153	159	164	170	170	176	176	181	187						

	12	12.6	13.2	13.8	14.4
12		136	142	153	159
12.6			153	159	170
13.2				170	176
13.8					
14.4					

	15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4
12	164	170	176	181	187	193	198	204	204	210	215				
12.6	176	181	187	193	198	204	210	215	221	227	232	238			
13.2	187	193	198	204	210	221	227	232	238	244	249	255	261		
13.8	193	204	210	221	227	232	238	244	249	249	261	272	278	283	
14.4	204	215	221	227	238	244	255	261	266	272	278	289	295	300	306

	4.2	4.8	5.4	6	6.6	7.2	7.8	8.4	9	9.6	10.2	10.8	11.4	12
3	17	17	22	22	28									
3.6	22	22	28	34	34	34	34							
4.2	22	28	34	34	34	34	40	45						
4.8	34	34	34	34	40	40	40	45	45	45				
5.4	34	34	34	40	40	40	45	45	51	51	51	51	51	

	15	15.6	16.2	16.8	17.4	18	18.6	19.2	19.8	20.4	21	21.6	22.2	22.8	23.4
15	215	221	227	238	249	255	266	272	278	289	295	300	306	312	323
15.6				255	261	272	278	289	295	306	312	317	323	329	340
16.2					272	283	295	300	312	323	329	334	340	351	357
16.8						295	306	317	329	340	346	351	357	363	374
17.4						312	323	329	340	351	357	363	374	385	397

Length of Exposure *Versus* Kill
(*Phloeothrips oleae* Costa.)

Tree No.	Exposure Min.	Standard Dosage Table %	Temperature F.	Relative Humidity %	Kill %	Ave.
1	30	17	63	70	[illegible]2	
2	30	23	[illegible]9	[illegible]1	8[illegible]	
3	30	2[illegible]	67	54	9[illegible]	89%
4	45	18	63	70	8[illegible]	
5	45	[illegible]	62	54	93	
6	45	22	67	54	98	91%
7	60	20	63	70	96	
8	60	23	60	51	100	
9	60	22	72	40	98	9[illegible]

The Influence of Temperature

In many parts of Spain where fumigation is practiced, temperatures between 30° and 40° F. are common in some parts of the day during the fumigation season. In citrus fumigation with sodium cyanide it is customary to discontinue the work at about 40° F. for reasons of danger of injury, reduced percentage of kill, crystallization of cyanide solution, etc. In view of these facts it seemed advisable to test the effectiveness of Cyanogas Calcium Cyanide fumigations at such temperatures.

It was found that at temperatures below 35° F. poorer kills were obtained, due perhaps to the reduced metabolism of the insect or to some unknown factor. As a result of these tests and other experience, it seems inadvisable to work at temperatures below 40° F.

INFLUENCE OF TEMPERATURE ON % KILL
(Phlocothrips oleae)

Cyanogas Calcium Cyanide							Sodium Cyanide					
Tree No	Temperature Degrees F	Relative Hum. %	Standard Dosage Table %	Method of Application	Exposure Minutes	Kill in %	Tree No	Temperature Degrees F	Relative Hum. %	Standard Dosage %	Exposure Minutes	Kill in %
1	33	90	20	Direct	60	43	1	33	90	10	60	50
2	33	90	26	Direct	60	93	2	35	90	20	60	94
3	33	90	32	Direct	60	93	3	33	90	30	60	77
4	34	81	20	Direct	60	72	4	34	81	16	60	88
5	34	81	25	Direct	60	91	5	34	81	11	60	54
6	41	62	20	Direct	60	100	6	41	62	16	60	99
7	41	62	20	Direct	60	100	7	42	55	15	60	100
8	42	62	22	Direct	60	98	8	42	55	17	60	100
9	42	59	28	Direct	60	100	9	44	51	15	60	99
10	46	59	25	Direct	60	98	10	44	51	16	60	100

Fumigation Inspection

In Spain it has been found that regulations are necessary to insure thorough work by the commercial fumigators. The growers are grouped together into cooperative syndicates whose officers have the power to let fumigation contracts to the fumigators. These contracts provide for non-payment for fumigation until such time as the results have been checked by inspectors of the syndicate. This check takes place twenty days after the fumigation. If a single living thrips is noted on any tree, this tree has to be re-fumigated. It may be seen that such a contract is very drastic since kills of 100% are not usually economically possible. Due to the fact that in many cases this system has not proven satisfactory, fumigation work has been undertaken by some of the provincial governments.

Open Air Dusting

A series of experiments was performed to determine the effectiveness of open air dusting in the control of the Oilve Thrips. In this work kills of between 80% and 90% were obtained by the use of 2 to 3 pounds of Cyanogas "A" Dust per tree. However, experience has taught the Spanish grower that higher kills are more economical, so this work was abandoned for the more thorough method of tent fumigation.

Resistance of Olive to Injury With Cyanogas

Olive trees were found to be very resistant to injury from Cyanogas Calcium Cyanide. After the fruit had become sufficiently hardened in the latter part of August absolutely

no injury resulted in any of the trees fumigated. In the olive tree cycle, blossoms occur the latter part of April, followed in May by the young fruit which ripens in November and December. As the harvest season is from November thru January, the fruit would have to undergo fumigation during the first half of the season. There is, however, no injury to be feared.

The usual method of harvest is that of clubbing the trees to knock the fruit to the ground. It is generally believed that this procedure also jars off the thrips and that better results will therefore be obtained by fumigation before harvest rather than after. There is no evidence, however, in support of this belief. Since no fruit injury results from the Cyanogas, the time of fumigation may be left to the grower's convenience.

Advantages of Cyanogas Over Sodium Cyanide For Olive Fumigation

(1) In tree fumigation under tents, regardless of method, the labor cost for tree coverage will be equal. Likewise the original cost of tents will be the same. However, when sulfuric acid enters into the process of fumigation it is certain to spatter from the pots or come into contact with the canvas in some way, burning holes which have to be patched, and thus reducing the life of the tent to three or four years. Since the cost of tents is the most expensive item in the fumigator's equipment, anything that will increase their life is of the utmost economic advantage. It may be safely estimated that the use of Cyanogas Calcium Cyanide will double the life of the tent over that resulting from the hole burning sulfuric acid method.

(2) Throughout the olive districts water is scarce and its use in fumigation necessitates a long haul and extra labor. Cans of sodium cyanide, and bulky sulfuric acid bottles must also be transported. Cyanogas Calcium Cyanide from which the evolution of HCN requires no extra materials, cuts the transportation problem to the limit.

(3) Another expensive item in sodium cyanide fumigation equipment is that of the sulfuric acid bottles and earthenware pot generators. These are not only expensive to begin with but are also frequently brokn, constituting a potential liability. The use of Cyanogas eliminates this equipment.

(4) In the mixing of chemicals for the generation of HCN from NaCN reasonable accuracy is necessary for uni-

form results. This accuracy requires extra time and extra labor. The mechanical measuring device on the FQSA duster is not only accurate but is rapidly performed.

(5) Seven men are necessary to operate a gang using sodium cyanide. These include four men to handle the tents, one man to measure trees, one man to weigh materials, and one man for dosing. Where Cyanogas Calcium Cyanide is used, the weighing and dosing is performed mechanically by one man, thus cutting the wages of one man from the operating expense.

(6) It is the experience of laborers that their clothing becomes acid-eaten and also frequent accidents occur which overcome or kill someone. Cyanogas is not caustic to clothing and serious accidents with it have never happened in this work.

In summarizing, it will be seen that the use of Cyanogas Calcium Cyanide saves the cost of tents in a six-year period, the wages of one man per day, the breakage cost of pots and bottles, the transportation cost of water and acid; and furthermore will give equal results with greater comfort in handling, greater accuracy in dosing, and greater speed of application than will be obtained with the sodium cyanide method.

Conclusions

(1) Open air dusting with Cyanogas Calcium Cyanide at the rate of two to three pounds to the tree resulted in a kill of 80% to 90% of the Olive Thrips.

(2) The application of Cyanogas at the rate of 20% of the Standard Dosage Table for Citrus, under tents, resulted in kills of from 98% to 100% of the Olive Thrips.

(3) Exposures of one hour resulted in better kills than exposures of 30 or 45 minutes.

(4) Fumigations performed at temperatures below 35 F resulted in unsatisfactory kills of the Olive Thrips.

(5) Direct applications gave better results with 30% less dosage than did indirect.

(6) Fumigations with Cyanogas between the months of October and March resulted in no injury to the olive trees.

(7) Cyanogas offers the fumigator great savings in cost of operation with equal effectiveness to and greater safety, rapidity, and accuracy in application than the sodium cyanide method.

EXPERIENCIAS SOBRE EL EMPLEO DEL CIANURO DE CALCIO EN LA FUMIGACIÓN DE LOS OLIVOS PARA COMBATIR LA PLAGA

De *Phlaeothrisps oleae*, Costa.

Desde que se generalizó el empleo de la fumigación de naranjos y olivos con el ácido cianhídrico, vienen realizándose estudios para perfeccionar su aplicación, haciéndola cada vez más práctica y económica. Un paso en este sentido corresponde al empleo del cianuro de calcio.

Durante el otoño e invierno pasados realizamos experiencias en los olivares de Mora de Toledo para estudiar la aplicación de este producto en la lucha contra la plaga del «arañuelo» *(Phlaeotrips oleae)*.

Utilizamos en estas experiencias cianuro de calcio del tipo denominado *Cyanogas Dust A.*, de la Sociedad Fumigadores Químicos, de Valencia (filial de la American Cyanamid Company, de Nueva York).

Se trata de un polvo finísimo, que pasa en la proporción de 80 por 100, por el tamiz de 200 mallas por pulgada francesa, según determación que hemos practicado, y con una riqueza en cianuro de calcio del 44,62 por 100, según análisis hecho por la Estación Agronómica de Madrid, el cual indica además la presencia de cianamida de calcio en la proporción de 3,57 por 100. La casa ofrece una pureza en cianuro de calcio, comprendida entre el 40 y el 50 por 100, amplitud de límites que sería de desear se redujese, pues una oscilación posible del 10 por 100 en la riqueza del principio activo, para un producto que posee como pureza máxima el 50 por 100, es, desde luego, excesiva para el cálculo de las dosis necesarias, de no tomar siempre como base el límite inferior.

La propiedad que posee el cianuro de calcio de reaccionar con el vapor de agua atmosférico produciendo ácido cianhídrico, es la base de su poder insecticida. El gas cianhídrico se produce, pues, sin la intervención de ácido alguno, de distinta manera a lo que ocurre con el procedimiento ordinario de fumigación con el cianuro de sodio, el cual precisa la intervención de ácido sulfúrico a más del agua necesaria para facilitar la reacción. El cianuro de calcio reacciona con el agua, dando lugar a la formación de hidrato de calcio y ácido cianhídrico (1):

$$(CN)_2\,Ca + 2\,H_2O = Ca\,(OH)_2 + 2\,CNH$$

(1) Prescindimos de otras reacciones secundarias, que tienen lugar por la presencia de cianamida de calcio y otros productos que acompañan al cianuro.

Se comprende según esto que para que el desprendimiento de ácido cianhídrico tenga lugar de una manera completa, precisa un íntimo contacto de las partículas del cianuro de calcio con aire que contega un cierto grado de humedad, y que, por el contrario, si el producto se guarda seco y fuera del contacto del aire, permanecerá inalterado.

Procedimiento operatorio.

Para facilitar la dosificación y distribución del cianuro de calcio en polvo, empleamos una máquina de la citada sociedad. Esta máquina va montada sobre una mesa baja, provista de manceras que permiten su fácil

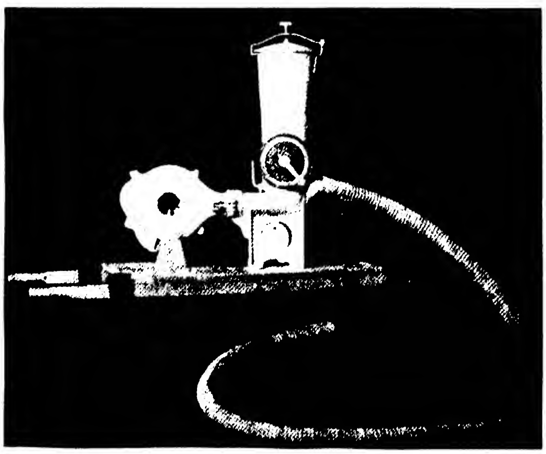


Fig. 1.ª
Máquina para fumigar con cianuro de calcio en polvo.

transporte por dos obreros, y consta esencialmente de tres partes: depósito de cianuro, aparato de medida y ventilador (fig. 1.ª).

El depósito es de forma tronco-cónica, con la base mayor hacia arriba, y lleva un agitador que se mueve al accionar el aparato de medida, con objeto de asegurar el cebo de éste.

El dosificador consiste esencialmente en un cilindro de eje horizontal, provisto de seis acanaladuras simétricamente dispuestas sobre su periferia. Este cilindro obtura la salida inferior del depósito, a la cual va presentando sucesivamente cada una de las acanaladuras, cuando se le hace

girar, mediante un manubrio que resbala sobre un disco vertical inmóvil dispuesto sobre el eje del cilindro.

Sobre este disco hay marcados seis puntos, que le dividen en partes iguales y corresponden al paso, por el orificio de salida del depósito de cianuro, de cada una de las acanaladuras citadas, las cuales se van llenando a medida que pasan, y van tapadas lateralmente hasta ocupar la posición opuesta, en que quedan libres sobre una cámara a la que llega el aire del ventilador, arrastrando el cianuro al tubo de salida en ella dispuesto.

A este tubo se adapta una manguera de goma, que permite guiar el cianuro bajo la lona que cubre el árbol.

La unidad que se mide es la cantidad que cabe en cada acanaladura del cilindro, y las máquinas están reguladas de forma que ese contenido es de 24 gramos. En la máquina con que realizamos las experiencias, comprobamos, después de repetidas pesadas, que las unidades eran de 20 gramos en vez de 24, por ello resultaron las dosis que empleamos inferiores a las calculadas con arreglo a unidades de 24 gramos.

Al comenzar el trabajo, y siempre que se llene el depósito, es conveniente dar una vuelta completa y descargar al aire el cianuro, al objeto de asegurarse de que no pasa ninguna división vacía. Hecho esto, para medir la dosis correspondiente a cada árbol basta mover lentamente el manubrio (pues con rapidez no se llenarían bien los alveolos) hasta contar el número de divisiones correspondiente, y accionar después el ventilador.

Operando siempre con cianuro reducido a polvo finísimo y muy seco, la máquina medidora funcionará bien de ordinario; pero sería muy conveniente poder comprobar con relativa facilidad si su funcionamiento es normal. Contribuiría a ello el poseer una disposición (rueda dentada y tornillo sin fin, por ejemplo) para garantizar que el movimiento del manubrio se verifica con la lentitud necesaria para asegurar el llenado de los alveolos; pues, tal como está hoy dispuesto, es fácil accionarla con rapidez que impida se llenen bien, mermando la cantidad calculada para cada árbol y sin que pueda esto comprobarse.

El procedimiento operatorio es el siguiente: cubicado el árbol, cubierto por la lona, y hallada la dosis necesaria de producto (en forma análoga a como se hace con el cianuro de sodio), basta medir la cantidad correspondiente a cada árbol en la máquina antes descrita e introducir el cianuro de calcio bajo la lona, accionando el ventilador que con este fin lleva la máquina y sosteniendo la manguera a cierta altura, para que se reparta uniformemente. Esto es de gran importancia para conseguir buenos resultados, pues si nos limitamos a accionar el ventilador sin observar la salida del cianuro, se corre peligro de que, acumulándose el polvo al chocar contra el suelo, tronco o hierbas, pierda el íntimo contacto con el

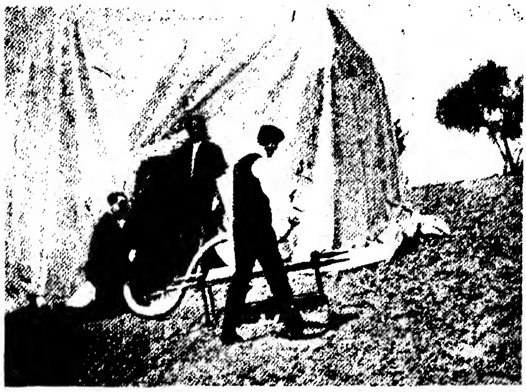


Fig. 2.ª
Fumigación de olivos con cianuro de calcio.

aire, necesario para que tenga lugar la reacción que origina el desprendimiento de ácido cianhídrico; si el cianuro de calcio se acumula, el desprendimiento de cianhídrico se hará mal y más lentamente, o, lo que es lo mismo, no se aprovechará más que una parte de su valor insecticida.

Siendo cada partícula de cianuro un foco de formación de ácido cianhídrico, debe procurarse repartirlas lo más uniformemente posible bajo la lona que cubre el árbol.

Para ello aconsejamos que sostenga un obrero la lona recogida a suficiente altura para que otro agachado pueda guiar el chorro de cianuro finamente pulverizado que envía el ventilador, procurando quede bien repartido por todo el árbol (figs. 2.ª, 3.ª y 4.ª), hasta que, cuando haya salido casi todo y vea puede escaparse algo o le llegue un poco de gas, se deja caer la lona, quedando el segundo obrero sosteniendo la manguera dirigida hacia arriba, pero desde fuera de la lona. Después de esto debe continuarse por breves momentos el funcionamiento del ventilador, para tener seguridad completa de que ha salido todo el cianuro.

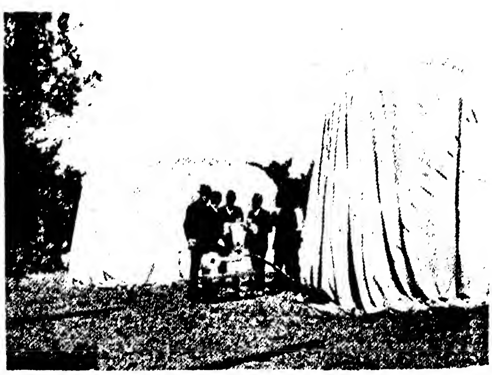


Fig. 3.ª
Fumigación de olivos con cianuro de calcio.

Dosis necesarias e influencia de la temperatura sobre las mismas.

Teóricamente, 100 gramos de cianuro sódico del 98 por 100 de riqueza (130 referida a cianuro potásico) producen igual cantidad de ácido cianhídrico que 200 gramos de Cyanogas con 46 por 100 de riqueza en

Fig. 4.ª
Reconociendo olivos fumigados.

cianuro de calcio. Es decir, que dos partes del cianuro cálcico empleado (con riqueza del 40 a 50 por 100) equivalen a una de cianuro sódico. Aunque (tanto en uno como en otro caso) hay diversas causas de pérdida que reducen la cantidad de CNH desprendido, prácticamente puede admitirse la equivalencia indicada como base de comparación para calcular las dosis.

En las experiencias realizadas durante los días 12 y 13 de Marzo tomamos dosis equivalentes a dos y dos y media veces las de la tabla número 1 de D. Leandro Navarro, considerándola referida a cianuro sódico, pues estas dosis (y aun aumentadas en un 30 por 100) son las que se emplean, según los casos, en la fumigación por el procedimiento de los generadores. Como la máquina utilizada media unidades de 20 gramos en lugar de 24, que son a las que nos referíamos en los cálculos, resultaron (como podrá observarse en el cuadro resumen de las experiencias) cantidades inferiores a dos y dos y media veces las de la tabla número 1, y que, en

algunos casos, coinciden con el doble de las que figuran en la tabla 3/4 del Sr. Navarro (o sea vez y media las de la tabla 1).

Las fumigaciones obtenidas fueron francamente buenas, pues los *Phlaeothrips* murieron. Para mayor garantía se guardaron insectos de 12 árboles en tubos, para observarlos al cabo de veinticuatro horas y comprobar si la acción del insecticida había sido completa o revivía alguno.

Se operó en condiciones excelentes de temperatura, pues estuvo comprendida entre 18 y 24°.

Experiencias de fumigación de olivos para combatir la plaga de «Phlaeothrips oleae» Costa, mediante el empleo de cianuro de calcio.

Número del árbol.	DIMENSIONES	Gramos de cianuro de calcio	PSICRÓMETRO Termómetro seco	Termómetro húmedo	Humedad relativa.	HORA	INSECTOS OBSERVADOS Después de la fumigación. Vivos.	Muertos.	Al cabo de 24 horas en tubos. Vivos.	Muertos.
	(*)									
1	10,5 × 15	160	20°	14°	48	12,15	»	149	»	35
2	8,7 × 11,9	100	»	»	»	12,17	»	48	»	36
3	11,1 × 14,7	160	19°	12°	38	13,32	1	63	»	21
4	11,1 × 15	160	»	»	»	13,34	»	»	»	»
5	11,4 × 15	160	20°	11,5°	30	15,30	»	97	»	60
6	11,4 × 15,4	180	»	»	»	15,32	»	192	»	38
7	11,4 × 15	180	19°	11°	31	16,54	»	263	»	66
8	11,4 × 16	180	»	»	»	16,47	»	236	»	»
9	8,7 × 12	100	18°	13°	53	9,32	»	75	»	56
10	9,6 × 13	120	»	»	»	9,34	2	235	»	»
11	8,4 × 13,5	60	20°	12°	32	10,49	»	44	»	45
12	10,8 × 13	80	»	»	»	10,51	»	296	»	36
13	8,3 × 8	60	22°	12°	23	12	»	48	»	43
14	7,2 × 10,2	80	»	»	»	»	»	252	»	»
15	9,4 × 14,5	120	23°	13°	25	13,10	»	162	»	»
16	8,1 × 11,3	80	»	»	»	14,42	»	226	»	78
17	10,2 × 15	120	23°	13°	25	14,44	»	65	»	»
18	8,7 × 13	80	24°	13°	21	15,55	»	320	»	»
19	10,2 × 14	120	»	»	»	15,53	»	155	»	»

Estos datos se refieren únicamente a las experiencias realizadas en Mora de Toledo los días 12 y 13 de Marzo, en el ensayo oficial de este producto.

El tiempo de exposición fué de una hora en todos los casos. Se operó con cielo despejado y sin viento; salvo en el caso de los dos primeros árboles y en los olivos 3.° y 4.°, en los que se levantó un poco la lona por el aire.

(*) La primera cifra indica la suma de lecturas en las escalas de la lona, y la segunda, la circunferencia del árbol cubierto.

En experiencias llevadas a cabo durante los meses de Octubre y Noviembre, ensayamos dosis comprendidas entre dos y tres y media veces las de la tabla número 1 del Sr. Navarro, y pudimos comprobar la gran influencia de la temperatura sobre la eficacia de la fumigación.

Trabajando a 6 y 7°, llegamos a emplear dosis equivalentes a tres veces las de la tabla número 1, y los resultados obtenidos no fueron buenos. Se observaron insectos vivos en proporción no despreciable, y recogidos en tubos algunos de los al parecer muertos, revivieron en parte al exponerlos al sol al cabo de dos días de la fumigación.

Esta defectuosa acción, en tales condiciones de ambiente, no debe extrañarnos; pues a fin de otoño o en invierno, y con temperatura de 5 a 6°, están los *Phlaeothrips* aletargados, guarecidos e inmóviles y con una actividad respiratoria reducidísima. Por consiguiente, la cantidad de ácido cianhídrico ingerida ha de ser mucho menor que con temperaturas superiores, en las que el insecto conserva mayor movilidad y actividad respiratoria; no ingiriendo dosis suficientes del gas tóxico, para producirle la muerte haría falta crear una atmósfera mucho más concentrada de cianhídrico, ignorando la dosis que pudiera ser necesaria para realizar una buena fumigación.

Conforme a lo expuesto, por bajo de 8 a 10° (sobre todo, siendo estas temperaturas máximas) no es aconsejable fumigar, pues los resultados serán seguramente dudosos o malos. Y no se crea que para trabajar a temperaturas inferiores de las señaladas bastaría aumentar la dosis en la proporción necesaria; pues, aparte del inconveniente económico que esto supone, no se conseguiría, en nuestra opinión, mejorar gran cosa los resultados.

Por otra parte, a esas temperaturas la difusión del gas cianhídrico ha de tener lugar de peor modo, y en este aspecto el cianuro de sodio quizá presente una cierta ventaja por desprenderse el gas en caliente, como consecuencia del calor desarrollado en la reacción; hay que considerar también que en el caso del cianuro de sodio el tiempo de exposición a la máxima concentración de gas es mayor que en el de calcio, porque el desprendimiento de CNH es en el primero mucho más rápido. Pero de todas maneras, por debajo de los límites señalados, creemos han de conseguirse resultados dudosos, con poca diferencia para ambos procedimientos (según tenemos comprobado), aun queriendo pasar los límites de una dosis económicamente posible.

Las consideraciones anteriores nos hacen pensar que, seguramente, no se saca en Mora el fruto que debiera obtenerse de la fumigación, por no aprovechar bien las épocas en que se tiene temperatura conveniente para realizar un buen trabajo. En realidad, el hecho principal que limita la posibilidad de fumigar, en cuanto al *Phlaeothrips* se refiere, es la pre-

sencia de huevecillos sin avivar, y, por consiguiente, en cuanto a principios de otoño deje de haberlos, será momento oportuno de hacerlo; mejor quizá que hacia fines de invierno, antes de la puesta, en que, aun disponiendo de igual temperatura, se hallan más esparcidos los insectos, incluso por el terreno, como consecuencia de las operaciones de recolección y poda.

Influencia de la humedad atmosférica.

El grado de humedad relativa de la atmósfera influye sobre la rapidez del desprendimiento del ácido cianhídrico. Según los estudios de W Moore, con una humedad relativa inferior a 35° el desprendimiento de dicho gas es demasiado lento (dura varias horas), y, por consiguiente, no podría utilizarse.

En cambio, con humedad relativa de 35° en adelante, el desprendimiento es muy rápido y casi total en la primera hora, variando muy poco con el aumento del grado de humedad relativa, en tanto éste no alcanza la cifra necesaria a la condensación de agua sobre las hojas. En estas condiciones el desprendimiento de gas no es normal, y podría, además, haber peligro de perjudicar al árbol; por lo cual (de la misma manera que con el procedimiento del cianuro sódico) no deberá fumigarse con humedad excesiva, esto es, cuando se observen las hojas mojadas, lo mismo que si lo están las lonas o el terreno. El cianhídrico se desprenderá imperfectamente, porque siendo muy soluble en el agua, allí donde las partículas de cianuro caigan sobre ella, una buena parte del CNH quedará retenida en disolución, disminuyendo la concentración de la atmósfera que rodea el árbol y, por consiguiente, la eficacia de la fumigación.

En las experiencias realizadas en Mora de Toledo, llegamos a operar con 24° de humedad relativa, y, sin embargo, los insectos morían, indicando esto un normal desprendimiento de gas, en aparente contradicción con los trabajos de Moore. Pero fácilmente se comprenderá que la humedad relativa bajo la lona, cubierto el árbol, ha de ser mucho mayor que al exterior, y para comprobar este extremo nos encerramos con el psicrómetro bajo la lona de un árbol sin cargar y anotamos las siguientes cifras:

	HUMEDAD RELATIVA
Al exterior	25
Bajo la lona y pasados 15 minutos de cubrir el árbol . .	45
» » » 25 » » » . . .	42
» » » 32 » » » . . .	46
» » » 37 » » » . . .	42

Como se ve, bajo la lona la humedad relativa era muy superior al límite señalado como necesario para asegurar un buen desprendimiento de gas, y presentaba una gran diferencia con la del exterior, debida a la transpiración de la planta. Esto rebaja el límite inferior de humedad relativa a que puede trabajarse, debiendo servir de guía el que no sea inferior a 35° bajo la lona, asegurándose de ello repetidas veces, siempre que al exterior baje de dicha cifra.

Acción sobre la planta.

En ninguno de los olivos tratados observamos lesión alguna, ni aun en los casos en que operamos a más altas temperaturas.

Conclusiones.

Como resumen de lo expuesto, pueden deducirse las siguientes:

1.° Trabajando a temperaturas comprendidas entre 8°, o mejor 10, y 25°, con dosis de Cyanogas comprendidas entre tres y media y una y media veces, las correspondientes a la tabla número 1 del Sr. Navarro, hemos obtenido buenos resultados, comparables a los que se obtienen empleando el cianuro de sodio y ácido sulfúrico a las dosis equivalentes.

La determinación exacta de la dosis más conveniente para cada caso podrá realizarse partiendo de las cifras indicadas, que la práctica podrá rectificar de acuerdo con las consideraciones expuestas. Pero en ningún caso creemos sea aconsejable emplear dosis inferiores al doble de las necesarias de cianuro de sodio.

2.° Lo anterior se refiere al producto *Cyanogas* con una riqueza de 40 a 50 por 100 de cianuro de calcio y un grado de finura del 80 por 100, con respecto al tamiz número 200.

3.° Con humedad relativa de 35° o inferior a ella, bajo la lona, no debe fumigarse; por lo cual, en cuanto al exterior descienda del límite fijado, debe determinarse la humedad debajo de la lona en un árbol sin cargar, al objeto de comprobar que se conserva superior a 35°, aunque al exterior sea más baja.

4.° Tampoco deberá fumigarse con las tiendas, hojas o terreno mojados. La gran solubilidad del ácido cianhídrico en el agua mermaría notablemente la eficacia de la fumigación, con riesgo de producir la caída de las hojas en el caso de estar mojadas. Asimismo debe suspenderse el trabajo cuando amenace lluvia.

Es de gran importancia que el cianuro de calcio quede repartido uniformemente en el interior de la lona, evitando se acumule en determinados sitios; pues ello disminuiría la rapidez del desprendimiento del ácido cianhídrico, con merma de su eficacia.

6.ª El procedimiento de fumigación con cianuro de calcio presenta, con respecto al del cianuro de sodio y ácido sulfúrico, la ventaja de ser de manejo más fácil y hasta menos peligroso, asegurando, además, una mayor duración y conservación de las lonas, por no exigir el empleo de ácido. El no necesitarse agua es también, en muchos casos, una ventaja no despreciable.

MIGUEL BENLLOCH,
Ingeniero Agrónomo.

Translated from the Spanish

EXPERIMENTS IN THE USE OF CALCIUM CYANIDE FOR THE FUMIGATION OF OLIVE TREES TO CONTROL THE PEST, *Phloeothrips oleae*, Costa.

Ever since the fumigation of orange and olive trees with hydrocyanic acid gas came into general use, research has been constantly carried on with a view to perfecting the methods employed, in order to make them more practical and economical. One step forward in this direction was made by adopting the use of calcium cyanide.

During the past autumn and winter we conducted experiments in the olive groves of Mora de Toledo in order to verify the value of this product for the control of the "arañuelo" (*Phloeothrips oleae*).

In these experiments we used a calcium cyanide known as "Cyanogas A Dust" furnished by the Sociedad Fumigadores Quimicos, of Valencia (a branch of the American Cyanamid Company of New York).

This is an exceedingly fine powder, 80% of which will, according to our findings, pass through a sieve of 200 meshes to the French inch. It has a strength of 44.62% of calcium cyanide, according to an analysis made by the Agronomical Station of Madrid, and in addition showed the presence of calcium cyanamid to the extent of 3.57 per cent.

The firm's offer is to deliver goods with a pure calcium cyanide content of between 40 and 50 per cent. It would be preferable if this margin were reduced, since a possible variation of 10% in the strenth of the active principal in a product with a maximum purity of 50%, is, of course, too great for accurate figuring of the quantities required, unless indeed, the lower limit be always taken as a working basis.

The property of calcium cyanide to react with the vapor of the air to form hydrocyanic acid gas, is the basis of its insecticidal value. The hydrocyanic acid gas is therefore formed without the use of any acid whatsoever, contrary to the usual fumigation methods with sodium cyanide, which require the presence both of sulphuric acid and sufficient water to produce the reaction. The calcium cyanide reacts with the water vapor causing the formation of calcium hydroxide and hydrocyanic acid gas. (Note 1)

$$Ca(CN)_2 + 2H_2O = Ca(OH)_2 + 2HCN$$

From this it is plain that in order that the generation of the hydrocyanic acid be complete, free contact of the particles of calcium cyanide with air containing a certain amount of humidity is necessary. On the other hand, if the material is kept dry and removed from contact with the air, it will remain unaffected and unchanged.

Manner of Operation

In order to facilitate the measuring and distribution of the calcium cyande dust, we use an apparatus furnished by the same company. This apparatus is set upon a low table which is equipped with handles like a plow so that it may be easily moved about by two workmen. It consists essentially of three parts: a cyanide reservoir, a gauging device and a fan (fig. 3).

The reservoir is conical in shape, with the broader base at the top, and is equipped with an agitator which, after the gauging device begins to function, moves in such a manner as to feed the latter.

The feeder consists essentially of a cylinder with horizontal axle, having six deep grooves symmetrically arranged on its surface. This cylinder stops up the lower outlet of the reservoir and, moved by means of a crank sliding on a fixed vertical disk fitted upon the cylinder axle, carries each of the groves forward in turn to the outlet.

(1) We omit other secondary reactions which occur owing to the presence of calcium carbide and other products that accompany the cyanide.

On this disk six points are marked off dividing it into as many equal parts which correspond to the movement past the outlet of the cyanide reservoir of each of the six grooves mentioned. These are filled as they pass and capped sidewise until they reach the opposite position, where they are released over a chamber that is accessible to the air from the fan. The draught set up by the fan carries the cyanide to the outlet tube set in this chamber.

A rubber hose is fitted to this tube to convey the cyanide underneath the canvas with which the tree is covered.

The unit measured off is the amount contained in each groove of the cylinder, and the apparatus is regulated to make that amount 24 grams. With the apparatus used for our experiments, however, we found the units, on repeated weighing, to be 20 grams instead of 24; and consequently the quantities actually used turned out to be less than those we had figured, on the basis of a 24 gram unit.

When starting work after the reservoir has been filled, it is advisable to give a complete turn and discharge the cyanide into the air, so as to make sure that no empty division is passed up. This done, the crank has only to be slowly turned (if turned with speed the grooves will not fill properly) in order to measure out the amount for each tree, using as many divisions as are necessary to give the correct dosage. The fan is then set in motion.

Provided a finely powdered and thoroughly dry cyanide is used, the gauge will work well as a rule; however it would be well to have some means of easily determining whether its operation is normal and correct. For this purpose an attachment (wheel with teeth or an "endless" bolt, for example) would be helpful to make certain that the movement of the crank maintains a sufficiently slow pace to insure the filling of the grooves. The way it is now arranged, the gauge can readily be moved with a speed that hinders complete filling and thus reduce the amount intended for use on tree, while no means are provided for checking this up.

The actual method is as follows: after measuring the cubic space occupied by the tree covered with canvas, and after determining the quantity of product required (in the same way as with sodium cyanide), there remains only to measure the amount needed for each tree, by means of the apparatus above described, and to force the calcium cyanide beneath the canvas by turning on the fan with which the

apparatus is equipped. The hose should be kept at a certain height so that the dust will spread uniformly. This is very essential to obtain good results; since, if the fan is set in motion without regard to the discharge of the cyanide, danger exists of the dust accumulating by contact with the ground, the tree trunk, or the grass and losing that free contact with the air which is necessary in order to bring about the reaction which causes the generation of hydrocyanic acid gas. If the calcium cyanide accumulates, the generation of the hydrocyanic acid gas will be slow and incomplete and what amounts to the same thing, only a fraction of its insecticidal value will be available.

As each particle of cyanide constitutes a nucleus for the formation of hydrocyanic acid gas, it must be borne in mind that these particles should be distributed as uniformly as possible beneath the canvas that covers the tree.

For this reason we recommend that one workman be assigned to hold up the canvas at a proper height while another, bending low, can direct the stream of cyanide dust, forced out by the fan so as to scatter it all over the tree (figs. [illegible], [illegible] and [illegible]) until practically all the material is discharged. When the inside workman finds that some of the gas is about to escape or spread to where he is standing, the canvas is lowered, while the second workman who is on the outside keeps the hose directed upward. The fan is then kept going for a short time in order to make absolutely sure that all the cyanide is discharged.

Quantities Required and Effect of Temperatures on Same.

Theoretically, 100 grams of sodium cyanide with a strength of 98% (130% as compared with potassium cyanide) will generate the same quantity of hydrocyanic acid gas as will [illegible] grams of Cyanogas, having a 46% calcium cyanide content. In other words, two parts of calcium cyanide with a strength between 40 and 50 per cent are the equivalent of one part of sodium cyanide. Although in both cases there exist various factors producing a loss or reduction in the amount of HCN generated, for practical purposes, the above mentioned proportions may be taken as a basis for comparison in estimating the quantities to be used.

In the experiments carried out on the 12th and 13th of March we took amounts equivalent to two and two and a half

times those given in the sodium cyanide Table No. 1 of Don Leandro Navarro, since these amounts (even increased by 30%) are the ones used, according to the case, in fumigation by the "pot" method. Since the apparatus we used afforded units of only 20 grams instead of 24, on which we had based our calculations, the amounts turned out to be (as may be seen from the tabulation of our experiments) less than two to two-and-a-half times those of Table 1 and which in certain cases are equal to double those given in Mr. Navarro's Table 3/4 (i.e. one-and-a-half those of Table 1).

The fumigation results obtained were evidently very good, as the *Phloeothrips* were killed. To make doubly sure, thrips taken from 12 trees were placed in tubes for observation at the end of twenty-four hours, to determine whether the insecticide had done a thorough job or whether some of the insects would revive.

Working conditions were excellent from the point of view of temperature, which fluctuated between 18 and 24 degrees centigrade.

Experiments in the Fumigation of Olive Trees for Controling the Pest "*Phloeothrips oleae*" Costa, by Means of Calcium Cyanide.

No. of the Tree	Dimension	Grams of Calcium Cyanide	Thermometer Dry	Psychrometer Thermometer Wet	Relative Humidity	Time	Insects Observed After Fumigation		After 24 Hrs. in Tubes	
							Alive	*Dead*	*Alive*	*Dead*
1	10,5x15	160	20	14	48	12,15		149		35
2	8,7x11,9	160				12,17		48		36
3	11,1x14,7	160	19	12	38	13,32	1	63		21
4	11,1x15	160				13,34				
5	11,4x15	180	20	11,5	30	15,30		97		60
6	11,4x15,4	180				15,32		192		38
7	11,4x15	180	19	11	31	16,54		263		66
8	11,4x16	180				16,47		236		
9	8,7x12	100	18	13	53	9,32		75		56
10	9,6x13	120				9,34	2	255		
11	8,4x13,5	60	20	12	32	10,49		44		45
12	10,8x13	80				10,51		296		36
13	8,5x8	60	22	12	23	12		48		43
14	7,2x10,2	80						252		
15	9,4x14,5	120	25	13	25	13,10		162		
16	8,1x11,3	80				14,42		226		78
17	10,2x15	120	23	13	25	14,44		65		
18	8,7x13	80	24	13	21	15,55		320		
19	10,2x14	120				15,53		155		

These figures refer only to the experiments carried out at Mora de Toledo on March 12th and 13th in an official trial of this product.

The time of exposure was one hour in each case. The sky was clear at the time and there was no breeze; except for the first two trees and olive trees 3 and 4 where the wind slightly raised the canvas.

(*) The first figure indicates the sum of the readings on the scales of the canvas, and the second indicates the circumferance of the covered tree.

In the experiments carried on during the months of October and November, we used quantities amounting to from two to two and a half times those given in Mr. Navarro's Table I, and we observed the importance of temperature in obtaining a thorough fumigation.

When working at 6 C and 7 C we had to use amounts equivalent to three times those shown in Table I, yet the results obtained were not satisfactory. A few live insects were observed, and a number of those that were apparently dead when placed in tubes, revived on being exposed to the sun two days after fumigation.

This unsatisfactory result under the conditions mentioned, should be no cause for surprise; since toward the end of autumn and during the winter with temperatures at 5 C to 6 C the *Phloeothrips* are in a state of lethargy and immobility, their respiratory activity being reduced to a minimum.

Consequently, the amount of hydrocyanic acid gas they breathe in is, of course, much less than at higher temperatures when the insect is more active and respires at a more rapid rate. Since they do not take in sufficient quantities of toxic gas to cause their death, it would be necessary to create an atmosphere charged with a much greater concentration of the gas. It has not however been determined just what quantity would be necessary to obtain this result under such conditions.

In accordance with the above, it is not advisable to fumigate at temperatures below 8 C to 10 C (particularly when these are maximum temperatures) as the results are bound to be either doubtful or poor. Nor should it be imagined that in order to work at lower temperatures than those mentioned, the quantity need only be proportionately increased; since, aside from the economic disadvantages which these involve, we are of the opinion that the results would not thereby be greatly improved.

On the other hand, at such temperatures the diffusion of the hydrocyanic acid gas will not be sufficient, and from this point of view sodium cyanide will probably offer an advantage, since heat is generated in addition to the gas produced by the reaction. It must further be considered that in the case of sodium cyanide, the time of exposure to the maximum concentration of the gas is longer than with calcium cyanide as the HCN in the first case is generated more rapidly. At any rate, below the minimum temperatures, we believe the results obtained would be doubtful and the difference between

the two methods (according to our experiments) would be slight, even though the limit of an economically feasible dosage was exceeded.

These facts lead us to believe that at Mora the crop that should be obtained through fumigation is not produced because advantage is not taken of the seasons that afford the temperatures desirable for effective results. In fact, the principal factor restricting the chances of successful fumigation, so far as the *Phloeothrips* is concerned, is the presence of small dormant eggs. Early in autumn when these are no longer present would be the most favorable time for fumigation, even better perhaps than towards the end of winter before the eggs are laid, when although the temperature be the same as in the autumn, the insects are more scattered and even found on the ground, owing to the operations of harvesting and pruning.

Influence of Humidity of the Air

According to the studies of W. Moore, the degree of humidity in the air affects the speed with which the hydrocyanic acid gas is generated. At a humidity under 35% the generation of HCN is too slow (taking several hours) and consequently it cannot be used.

On the other hand, at a humidity of 35% and up the generation proceeds rapidly and almost completely within the first hour, and varies only slightly upon further increase in humidity, up to the point where it is so high as to cause the vapor to condense into water upon the leaves.

Under such conditions the generation of the gas is not normal and danger of injuring the tree would exist; accordingly (just as in the sodium cyanide treatment) fumigation should not be done when there is excessive humidity, that is, when the leaves, the canvas, or the ground beneath are damp. The gas will generate only partially because, being very soluble in water, a large percentage of the HCN will go into solution in such places where the particles of cyanide come into contact with it. This has the effect of diminishing the strength of the charge in the air surrounding the tree, and accordingly reducing the effectiveness of the fumigation.

In the experiments carried on at Mora De Toledo, we also worked with a humidity of 24%. Even at this low humidity the insects were killed indicating normal generation of gas in apparent contradiction to the findings of Moore

Yet it will easily be seen that the relative humidity beneath the canvas when the tree is covered must necessarily be much greater than on the outside. In order to verify this point, we stationed ourselves underneath the canvas of one untreated tree, with our psychrometer, and noted the following results:

		Relative Humidity %
Outside		[illegible]
15 [illegible]	[illegible] after the tree was covered [illegible] minute	1[illegible]
	[illegible]	1[illegible]
	[illegible]	1[illegible]
	[illegible]	1[illegible]

As can be seen, beneath the canvas, the relative humidity was much greater than the lower limit required for a satisfactory generation of the gas. The relative humidity under the tent was much higher than that on the outside, due to the transpiration of the plant. This reduces the lower limit of relative humidity at which work can be carried on, and [illegible]% beneath the canvas should be considered a minimum for this purpose. Repeated tests of this should be made every time the humidity outside the tent falls below this figure.

Effect Upon the Plant

We observed no injury whatever in any of the olive trees treated, not even in instances where we worked at high temperatures.

Conclusions

In resume of the preceding, the following conclusions may be drawn:

1. Working at temperatures between 5 C. or preferably 10 C. and 25 C. with amounts of Cyanogas between three and a half and one and a half times those shown in Mr. Navarro's Table I, we have obtained satisfactory results comparable to those obtained by the use of sodium cyanide and sulphuric acid in their equivalent amounts.

The exact determination of the most suitable amount in each instance should be based upon the above figures which, in practice, can be modified in accordance with the considerations previously mentioned. In no case do we consider it advisable to use amounts under twice those required with sodium cyanide.

II. The foregoing applies to Cyanogas having a strength of 40 to 50 per cent of calcium cyanide and a fineness of 80% relative to a number 200 sieve.

III. At a relative humidity of 35% or less beneath the canvas, fumigation should not be performed; accordingly, as soon as the humidity on the outside falls below this limit, that beneath the canvas of an untreated tree should be determind in order to make sure that it is maintained at over 35%, even though it be lower on the outside.

IV. The fumigation should not be performed when the tents, the leaves or the ground are damp. The great solubility of the hydrocyanic acid gas in water would considerably lessen the efficacy of the fumigation and might even cause the leaves to fall in case they were damp. Likewise, with rain threatening, the work should be delayed.

V. It is very important that the calcium cyanide be uniformly distributed beneath the canvas and that it should not accumulate in a few places, since this would diminish the speed with which the gas would be generated, and thus reduce its effectiveness.

VI. The process of fumigation with calcium cyanide compared to that of sodium cyanide and sulphuric acid offers the advantage of being more easily performed, of being less dangerous, and assuring, moreover, greater life of the tents, since it does not require the use of acid. The fact that no water is needed offers, in certain instances, an advantage that is not to be despised.

MIGUEL BENLLOCH,
Agricultural Engineer.

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SECTION 2

FUMIGATION—
GREENHOUSES AND MUSHROOM HOUSES

Greenhouse Fumigation with Cyanogas Calcium Cyanide

The use of hydrocyanic acid gas as a greenhouse fumigant has never been popular with the growers for several reasons. The method used in producing hydrocyanic acid gas was by the action of sulphuric acid on sodium cyanide in pots or jars. Fumigation with a low concentration over a long period of time was impossible by this method since the gas is all evolved at one time and soon falls below a lethal concentration due to leakage. To obtain a satisfactory kill it was necessary to use high dosages for a short period of time. These high dosages necessitated a ventilation of the house at the close of the fumigation with the resultant chilling of the house. The use of a high concentration was liable to cause serious injury to the plants.

Fig. 12. Adult White Flies Killed by Fumigation with Cyanogas Calcium Cyanide

Very recent experiments have shown that a low concentration for a long period of time is more fatal to the insect than a high concentration for a short period of time. Cyanogas Calcium Cyanide gives off its gas for a long period of time, and thus eliminates the undesirable features inherent to the use of sodium cyanide. The advantages of Cyanogas Calcium Cyanide as a greenhouse fumigant were quickly recognized by Mr. E. R. Sasscer, Dr. C. A. Weigel and Mr. C. F. Doucette of the Bureau of Entomology, United States Department of Agriculture. They conducted extensive experiments to determine the tolerance of plants and the degree of insect control resulting from the use of varying dosages for different fumigation periods. The results of these experiments were published in the Journal of Economic Entomology, Vol. 17, No. 2, April, 1924, p. 214, "Recent Developments in Greenhouse Fumigation with Hydrocyanic Acid Gas", E. R. Sasscer and C. A. Weigel, and in Vol. 18, No. 1, February 1925, p. 137.

Calcium Cyanide as a Greenhouse Fumigant

During the past summer samples of calcium cyanide in granular and dust form were received from Dr. Wm. Moore and experiments were undertaken to determine their value as greenhouse fumigants. Preliminary experiments in a 200 cubic foot box with the dust were made and more recently similar tests were conducted under actual greenhouse conditions. In the box tests the calcium cyanide dust was spread over damp newspapers in amounts equivalent to from one-half to one ounce of sodium cyanide per 1,000 cubic feet and the plants were exposed for one hour to the gas evolved. Two species of aphids were used viz: *Macrosiphoniella sanborni* on chrysanthemums in experiments 1 to 9, and *Illinoia pelargonii* on geraniums in experiment 10. Vinca, Jerusalem cherry, Martha Washington geranium, begonia, and Kentia palms were also included and escaped injury. The ¾ ounce rate caused slight tip burning on Lantana and snapdragon, and the 1 ounce rate on chrysanthemums. These results are shown in Table II.

TABLE II. SHOWING CONTROL OBTAINED WITH CALCIUM CYANIDE IN BOX FUMIGATION EXPERIMENTS

Exp. No.	Dosage NaCN in Ounces	Temperature °F	Humidity %	Interval in days	Condition after fumigation dead	Condition after fumigation alive	Control %
1	¼	71.6	85	1	79	94	45.6
2	do	69.2	90	½	370	7	98.1
3	¾	69.4	90	1	185	2	98.9
4	do	71.6	90	1	111	50	68.9
5	do	72.5	69	1	368	15	96
6	1	74.3	67	½	280	0	100
7	do	68.9	91	1	118	15	88.7
8	do	80.6	64	1	165	2	98.8
9	do	82.4	65	1	925	30	96.7
10	do	80.6	64	1	830	0	100

In the ½ ounce equivalent dosage accurate records of mortality could not be made the same day because some individuals revived after being brought into fresh air. The aphids were only stupefied by fumigation at the ¾ ounce rate when exposures lasted 15, 30, and 45 minutes respectively, and most of them soon recovered.

After these tests were completed it was learned that spreading the dust directly on the moist newspapers caused complex reactions which may have reduced the amount of hydrocyanic acid gas actually released.

Plant tolerance tests of the dust were then made under greenhouse conditions. For this purpose 8 varieties of plants known to be very sensitive to hydrocyanic-acid gas were selected. Ten plants of each variety were fumigated at rates equivalent to ½, ¾ and 1 ounce of sodium cyanide per 1,000 cubic feet for one hour. The temperature and

TABLE III. SHOWING TOLERANCE OF DIFFERENT VARIETIES OF PLANTS WHEN FUMIGATED UNDER GREENHOUSE CONDITIONS WITH CALCIUM CYANIDE

Host	Degree of burning at dosages equivalent to sodium cyanide in ounces ½	¾	1
Ageratum	Slight	None	Severe
Coleus	None	None	None
Artemisia	None	None	Slight
Heliotrope	Very slight	Very slight	Severe
Jasminum grandiflorum	Tip very slight	Tip slight	Tip severe
Lantana elegantissima	None	None	None
Ipomoea grandiflora	None	None	Slight
Salvia	None	Slight	Severe

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humidity conditions for these experiments were as follows: 73° F., and 84%; 72°F., and 75%; and 68 F., and 83%.

The dust was applied in the units to be fumigated by means of a small hand duster to insure equal distribution. Since hydrocyanic-acid gas is given off when the particles of calcium cyanide dust are exposed to moist air it was assumed that by forcibly blowing the material into a greenhouse a nearly complete reaction should take place resulting in a maximum liberation of gas. Encouraged by the slight degree of injury indicated in Table III, a larger house of approximately 18,000 cubic feet of space involving many varieties of bedding and ornamental plants was fumigated in the manner just described, and with similar results.

From the evidence of plant tolerance thus far obtained with very susceptible plants it seems likely that this material can be adapted for greenhouse fumigation purposes. However, considerable investigation remains to be done before its status as a greenhouse fumigant can be definitely assured. These investigations involve (1) perfecting methods of application, (2) determining the rate of evolution of gas under varying atmospheric conditions, and (3) ascertaining its insecticidal efficiency.

Fig. 2-2.—Applying Cyanogas "G" Fumigant for Greenhouse Fumigation. Note Fruit-Jar Container with Perforated Top.

FURTHER DATA ON THE USE OF CALCIUM CYANIDE AS A GREENHOUSE FUMIGANT

By C. A. Weigel, *Associate Entomologist, Fruit Insect Investigations, Bureau of Entomology, Washington, D. C.*

ABSTRACT

Comparative results of three series of fumigation tests in a box of 200 cubic feet capacity, using $Ca(CN)_2$ dust and granular $Ca(CN)_2$ at rates of ½ ounce per 1,000 cubic feet, and NaCN at the rate of ¼ ounce per 1,000 cubic feet with exposures lasting from 1 to 7 hours inclusive, and 15 hours, (or all night), on four species of aphids, namely, *Myzaphis* sp. on rose, *Aphis rumicis* on nasturtium, and *Macrosiphoniella sanborni* and *Rhopalosiphum rufomaculata* on chrysanthemum, are presented in the table. Overnight fumigation gave 100% mortality in each test.

Twenty five large commercial greenhouses were fumigated recently using ¼ ounce of granular $Ca(CN)_2$ for each 1,000 cubic feet of space, all night and an excellent control of *Myzaphis* sp. with negligible burning on roses resulted. Other tests gave similar results with *Myzus persicae* on carnations, *Illinoia pisi* on sweet peas, and *M. sanborni* on chrysanthemums. A one ounce dosage in orchid houses killed 100% Boisduval scale, *Diaspis boisduvalii*, and 52% of the chaff scale, *Parlatoria proteus* without injury to flowers.

$Ca(CN)_2$ is given off rather slowly and may require longer exposure than NaCN. It is however easier to use and, for that reason, may be more generally adopted by florists.

In an article entitled "Recent developments in greenhouse fumigations with hydrocyanic-acid gas" which was published in the April, 1924, issue of the JOURNAL OF ECONOMIC ENTOMOLOGY, the results of some preliminary experiments with calcium cyanide were presented. In that article it was pointed out that this material might very likely be adapted to greenhouse fumigation purposes.

During the current year experiments have been conducted for the purpose of securing answers to the two following questions: How soon after exposing calcium cyanide to the atmosphere of a fumigation box will the gas evolved therefrom reach a satisfactory killing concentration? Is it practical and effective to run overnight exposures at a concentration as low as ¼ ounce of calcium cyanide per 1,000 cubic feet of air space?

To determine the first question tests were made in a box of 200 cubic feet capacity, using calcium cyanide dust in one series, granular calcium cyanide in a second, and sodium cyanide, as a check, in the third. The lengths of exposures were 1, 2, 3, 4, 5, 6, 7, and 15 hours each, the last representing a full overnight exposure. Chrysanthemums infested with the black chrysanthemum aphid, *Macrosiphoniella sanborni* (Gill), and the green chrysanthemum aphid, *Rhopalosiphum rufomaculata* (Wils.), nasturtiums infested with *Aphis rumicis* Linn., and roses infested with *Myzaphis* sp., were used. The dosages employed in the first and second

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series were ½ ounce of calcium cyanide in dust and granular forms respectively which is approximately equal to ¼ ounce of NaCN or the strength used in the third series. The calcium cyanide dust and the granular calcium cyanide used in these tests were applied by spreading them on newspapers placed on the floor of the box. In the sodium cyanide series the gas was generated by the usual "pot method," i. e., by adding the chemical to the required amount of water and acid.

It is evident from the results of these tests with calcium cyanide dust and sodium cyanide as presented in Table 1 that a satisfactory mortality was obtained only with *R. rufomaculata* in the one-hour exposure with both materials, the other species exhibited greater resistance. This checks well with the results usually obtained by the pot method. The granular calcium cyanide acts more slowly than either of the other materials. At the end of the second hour a higher and more consistent mortality resulted in almost all cases. Thereafter the effectiveness increased with the length of exposure, resulting in a 100 per cent mortality at the end of 15 hours or overnight exposure.

The practical significance of these results is that in very tight boxes or greenhouses or when it is not desirable to fumigate all night at this strength the houses may be aired at the end of two hours. For older houses which are often leaky the exposure may extend throughout the night since the leakage causes a decrease in concentration.

Practical Greenhouse Tests

In determining the practical value of fumigating commercial greenhouses overnight with calcium cyanide, preliminary tests were tried in greenhouses in Washington, D. C., with encouraging results. Later this phase of the work was transferred to the Willow Grove,[1] Pennsylvania, field station, in charge of Mr. C. F. Doucette, because of the close proximity of that station to many large rose and other floral greenhouses. During the last three months there were fumigated about 25 large houses, the plants of which were infested with species of aphids, primarily *Myzaphis* sp.

In these experiments the duration of the exposure was from 12 to 15 hours, usually beginning about 5.30 p. m. and ending the following morning not later than 7 o'clock. The size of the houses varied from 16,000 cubic feet to 266,800 cubic feet. A dosage of only ¼ ounce of the granular form of calcium cyanide is used for every 1,000 cubic feet. The

[1]This station is conducted in cooperation with the Bureau of Plant Industry, Pennsylvania Department of Agriculture, C. H. Hadley, Director.

TABLE I.—SHOWING RESULTS OF BOX FUMIGATION TESTS IN WHICH ½ OUNCE OF CALCIUM CYANIDE DUST, ½ OUNCE OF GRANULAR CALCIUM CYANIDE, AND ¼ OUNCE OF SODIUM CYANIDE, RESPECTIVELY, PER 1,000 CUBIC FEET OF AIR SPACE WERE USED

				Rose[1]		Nasturtium		Chrysanthemum[2]			
				Myzaphis sp.		A. rumicis		M. sanborni		R. rufomaculata	
Fumigant	Exposure in hours	Temp.	Hum.	No. of specimens	Control	No. of specimens	Control	No. of specimens	Control	No. of specimens	Control
		°F.	Percent		Percent		Percent		Percent		Percent
$Ca(CN)_2$ Dust	1	69	76	163	56.4	90	18.8	676	62.2	278	82.7
Granular $Ca(CN)_2$	1	69	67	74	13.5	78	24.3	47	19.1	28	17.8
NaCN	1	67	71	115	61.7	55	18.1	677	52.1	255	81.1
$Ca(CN)_2$ Dust	2	74	47	287	81.1	326	83.1	421	92.8	36	100.
Granular $Ca(CN)_2$	2	67	66	93	61.2	29	55.1	313	85.9	127	92.9
NaCN	2	70	51	45	66.6	124	45.9	332	68.6	178	82.5
$Ca(CN)_2$ Dust	3	66	71	110	85.4	293	86.	424	98.3	139	99.2
Granular $Ca(CN)_2$	3	69	81	309	41.4	46	52.1	306	79.	174	85.
NaCN	3	64	60	29	93.1	38	86.8	398	81.4	85	100.
$Ca(CN)_2$ Dust	4	69	63	37	89.1	132	91.6	425	99.7	47	100.
Granular $Ca(CN)_2$	4	67	71	31	90.3	43	55.8	384	89.3	168	99.4
NaCN	4	70	55	37	83.7	71	81.6	187	85.	205	91.2
$Ca(CN)_2$ Dust	5	68	67	126	86.5	338	89.9	340	100.	90	100.
Granular $Ca(CN)_2$	5	64	65	117	86.3	111	75.6	205	89.2	156	95.5
NaCN	5	67	53	27	77.7	186	91.3	341	97.6	226	100.
$Ca(CN)_2$ Dust	6	67	80	42	100	387	94.	299	99.6	25	100.
Granular $Ca(CN)_2$	6	62	64	55	80	133	73.6	238	91.5	41	85.5
NaCN	6	65	66	47	89.3	52	96.1	418	100.	26	100.
$Ca(CN)_2$ Dust	7	64	79	225	96.4	181	99.4	339	100.	5	100.
Granular $Ca(CN)_2$	7	70	55	75	94.6	145	80.	150	100.	63	100.
NaCN	7	69	67	26	87.	101	97.	236	100.	124	100.
$Ca(CN)_2$ Dust	15	71	64	63	100.	100	100.	569	100.	28	100.
Granular $Ca(CN)_2$	15	63	69	121	100.	225	100.	391	100.	331	100.
NaCN	15	69	63	17	100.	113	100.	556	100.	396	100.

[1]Burning beginning with sixth hour.

[2]More or less burning throughout the series.

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chemical was applied by sprinkling it evenly on the soil in either one or more walks or aisles, depending on the width of the house to be fumigated. The temperatures ranged from 59°F. to 73°F. and the per cent humidity was from 78 to 95.

The mortality in most of the tests was 100 per cent except in several instances where excessive leakage occurred due to broken glass, loose-fitting doors, or passageways which, under the existing conditions, could not be tightly closed. The outstanding features of these experiments were the excellent control and the negligible degree of burning from the gas on the roses.

In addition to these experiments, others were conducted in commercial houses where crops of carnations infested with *Myzus persicae* (Sulz.), sweet peas infested with *Illinoia pisi* (Kalt.), and chrysanthemums infested with *Macrosiphoniella sanborni* (Gill.), were fumigated with similar results. Large orchid houses, containing cattleyas, cypripediums, and other varieties, were fumigated at a *one*-ounce rate of dosage, resulting in a mortality of 100 per cent of the Boisduval scale, *Diaspis boisduvalii* Sign., and of 52 per cent of the chaff scale, *Parlatoria proteus* (Curtis). It is of interest to note here that in some cases the orchids were in flower and passed through the fumigation without injury.

A satisfactory control was obtained with the greenhouse white fly, *Trialeurodes vaporariorum* (Westw.), on snapdragons, marguerites marigolds, sweet peas, salvias, fuschias, and primulas, at the ¼ ounce dosage.

Conclusions: Fumigation with calcium cyanide in granular form, used in a low concentration, as ¼ ounce per 1,000 cubic feet of air space (approximately equal to ⅛ ounce of sodium cyanide), with an exposure lasting over night, appears to be an effective and practical method of controlling aphids and the adults of white flies that are ordinarily encountered on roses, chrysanthemums, carnations, and the other commercial crops mentioned in this article. Hardier plants, as palms and orchids, will apparently withstand without injury a much higher concentration.

It must be remembered, however, that if this dosage were increased and the same length of exposure employed, injury to the above mentioned crops would very likely occur. The longer exposure seems more desirable when using calcium cyanide than when using sodium cyanide and generating the gas by the pot method. With the latter it is generally the practice to use higher concentrations and shorter exposures, usually not longer than one hour, because the gas is assumed to be given off

within the first few minutes after the sodium cyanide is added to the acid and water; while in the case of calcium cyanide the evolution of the gas is apparently somewhat slower since it is dependent on the action of the atmospheric moisture.

From the foregoing results it would seem that calcium cyanide may be more generally adopted by florists for fumigating purposes. It is easier to use than sodium cyanide, since it does away with the cumbersome weighing and measuring necessary in fumigation by the pot method.

DIRECTIONS FOR GREENHOUSE FUMIGATION

PREPARATION OF THE HOUSE

The house should not be watered for twenty four hours preceding the fumigation to insure dryness of the plants. During the fumigation the temperature should be between 55° Fahr. and 70° Fahr., rising rather than falling. This will prevent undesirable condensation of moisture on the leaves. The best conditions are obtained by maintaining the house at not too high a temperature during the daytime preceding the fumigation. Fumigations should be carried out during a calm, or nearly calm night, since high winds increase the leakage of the gas from the house and may result in a poor kill. The walks need not be absolutely dry but should have no standing water.

In England, the plants in individual pots are usually watered with rain water by means of a sprinkling pot. Under such conditions the benches, walks and other portions of the house are dry, producing a much drier condition of the atmosphere than obtains in the greenhouses of the United States which are wet down with a hose. In the summer, when the ventilators of these glasshouses are open, they become so dry and the relative humidity is so low that the Cyanogas Calcium Cyanide does not readily decompose. Under these conditions, the directions concerning the watering of the house should be modified. It is recommended that the walks be wet down one or two hours before fumigation and the ventilators closed in order to raise the relative humidity within the house but care should be taken not to have drops of water on the plants.

THE FUMIGATION

Fumigation is started at dark by simply scattering the Cyanogas "G" Grade evenly on the walks, after which the house is closed for the night, Fig. 2-2. The material is scattered evenly from end to end of the house on several of the walks. It is unnecessary to treat every walk. If it is inconvenient to weigh out the Cyanogas it may be measured with sufficient accuracy on the basis of one-half ounce for the average level tablespoonful. By the following morning the gas will have practically disappeared, hence it is not necessary to open the ventilators and air out the house.

DOSAGE

All fumigations, except where tender plants are present, should be started by using one-quarter ounce of Cyanogas Calcium Cyanide for each 1,000 cubic feet of space, the correct dosage for a tight house. Should the one-quarter ounce dose fail to give the desired kill, because of a leaky house, the fumigation should be repeated in about one week, using one-third ounce per 1,000 cubic feet. In this manner, the correct dosage for each individual house will be determined without danger to the plants. A fumigation with one-quarter ounce of Cyanogas per 1,000 cubic feet, conducted as herein directed, is safe to normal greenhouse crops, such as roses, chrysanthemums, carnations, orchids, ferns, tomatoes and cucumbers.

In the work of the past year a large number of greenhouses have been successfully fumigated in the United States and a number of glasshouses have been fumigated in England. These fumigations cover a very wide range if not all of the commonly grown greenhouse plants and indicate that the one-fourth ounce dosage, if used as per above directions, is safe for practically all plants. The most tender plants appear to be Sweet Peas, Snapdragons, *Asparagus plumosus*, and *Asparagus springeri*. Jasminum, Artillery plant, Marguerite, Wandering Jew, and lettuce also seem to be tender plants. Should there be large numbers of these plants in the house, greatest care should be exercised to insure the favorable conditions given above. It is better in such cases to start with a lower dose such as one-eighth ounce per 1,000 cubic feet.

HOW TO MEASURE A GREENHOUSE AND DETERMINE THE QUANTITY OF CYANOGAS CALCIUM CYANIDE TO USE

To determine the exact quantity of Cyanogas to be used in the fumigation of a greenhouse, it is recommended that the capacity of the greenhouse be determined by actual measurement. This calculation is not difficult if the following method is used.

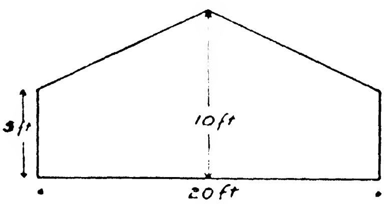

Fig. 3 2. Cross Section of an Even Span House. Length 200 feet.

In the case of the even span house, Fig. 3 2, measure the height at the highest point (10 ft.), add the height of one of the side walls (5 ft.) and divide the sum by two, thus obtaining the average height (7½ ft.) of the house. Multiply the average height (7½ ft.) by the width (20 ft.) to obtain the area of the end of the house (150 sq. ft.). Multiply the area of the end (150 sq. ft.) by the length (200 ft.) to obtain the capacity of the house (30,000 cu. ft.). Since ¼ ounce of Cyanogas is used to each 1,000 cubic feet, the above house would require thirty one quarter ounces or 7½ ounces of Cyanogas.

The three quarter span house, Fig. 4 2, is not so simple to calculate, as three fourths of the house "A" has a different average height than the other fourth of the house "B". Measure the height at the highest point (12 ft.), add the height of the wall on the side "A" (5 ft.) and divide the sum by two, thus obtaining the average height (8½ ft.) of the side "A". This average height is then multiplied by the width of the side "A" (18 ft.),

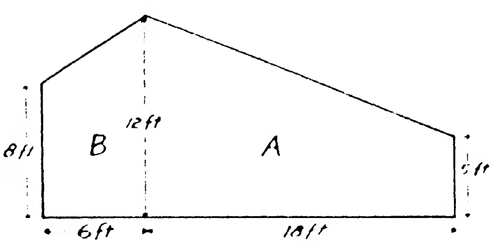

Fig. 4 2. Cross Section of a Three Quarter Span House. Length 200 feet.

the distance from the wall of the house to the highest point, obtaining the area of this side (153 sq. ft.). The height at the highest point (12 ft.) is then added to the height of the wall on the side "B" (8 ft.) and the sum divided by two to obtain the average height (10 ft.) of the side "B". Multiply the average height (10 ft.) by the width of the side "B" (6 ft.), from the wall to the highest point, obtaining the area of the side "B" (60 ft.). The area of the side "A" (153 sq. ft.) is added to the area of the side "B" (60 sq. ft.) to obtain the total area (213 sq. ft.) of the end of the house. This area is multiplied by the length (200 ft.) to obtain the capacity of the house (42,600 cubic feet). For practical purposes one may ignore the 600 cu. ft., making the amount of Cyanogas required for this house 42 one-quarter ounces or 10½ ounces.

Some growers may feel that the calculation of the capacity of the house is too bothersome. Such growers may determine the number of square feet under glass by multiplying the length by the width of the house. Assuming the average height of the house as six feet, the dosage would be 1½ ounces of Cyanogas for each 1,000 square feet under glass. If the house is higher than six feet this dosage will be under the normal dosage and may not give a perfect kill. The house should then be refumigated, increasing the dosage ½ ounce per 1,000 square feet until the correct amount for the house has been determined.

ADVANTAGES OF CYANOGAS AS A GREENHOUSE FUMIGANT

1. Cyanogas Calcium Cyanide makes it possible to maintain a low concentration of gas for a long period of time, thereby affording a greater margin of safety to the plants.

2. It is unnecessary to air out the house, hence the plants are not chilled.

3. Cyanogas fumigations kill the insects on the lower parts of the plants just as well as on the upper portions.

4. The method is easy to use and has already met with wide adoption by practical growers.

5. Safer to use.

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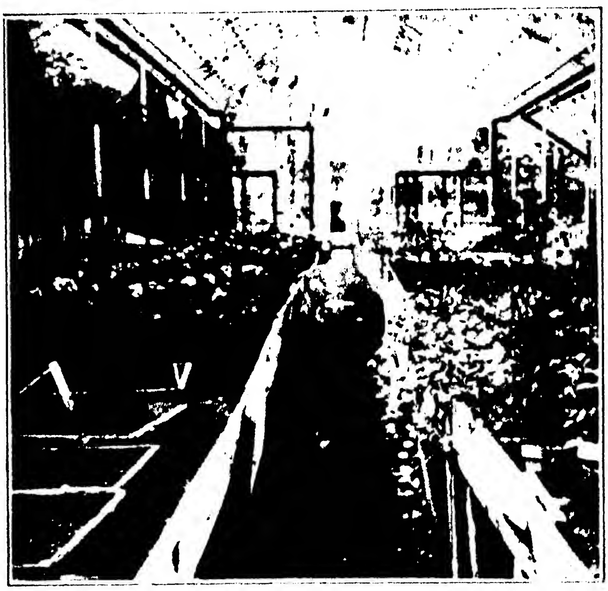

Placing Calcium Cyanide in Greenhouse for Fumigating to Control Insects

F. P. WILLITS, *Secretary of Agriculture*
C. H. HADLEY, *Director, Bureau of Plant Industry*

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SUMMARY

A survey of greenhouses in Pennsylvania shows nearly all suffer severe losses from insects. Plant lice were present in most of the houses visited and twenty-two other pests were reported present in harmful numbers in some houses.

Calcium cyanide (a new material) offers cheap and effective fumigation for greenhouses.

For success with calcium cyanide fumigation the following steps must be observed.

1. Calculate accurately the cubic space of your greenhouse. (See page 5.)

2. Be sure your house is free from plants which are especially susceptible to injury from fumes of cyanide. (See page 4.)

3. Accurately weigh out the amount of material needed. Start with one-eighth ounce to 1000 cubic feet. If your house is fairly tight this dosage will be sufficient.

4. Always start the fumigation about one hour after sundown—never before. Choose a still night.

5. Do not water the greenhouse for at least twenty-four hours before fumigation.

6. The temperature should be between 55 and 70 degrees Fahr., and it should be a rising temperature.

Greenhouse Fumigation

By [illegible]

CONTENTS

GREENHOUSE INSECT PESTS

A recent survey made by the Pennsylvania Department of Agriculture through the Bureau of Plant Industry showed the greenhouse growers of the state are confronted with a heavy loss at all times due to the insect pests of the plants grown under glass. It is not the purpose of this bulletin to discuss all these pests and their control, but it seems well at this point to present briefly some of the more outstanding facts shown by the survey.

A total of [illegible] greenhouses were visited, located in [illegible] counties of the state. Loss by insects was evident in all of the houses, if not directly by the ravages of the pests, then by the labor and cost of materials used in controlling the pests. Complete or satisfactory control of all pests was evident in but few of the houses; in these cases the loss occasioned by the pests themselves was reported as practically nil.

It is interesting to note that plant lice or aphids were present in a larger number of houses than any other single group of insects, the number being 302 houses out of the total. Red spiders were present in 197 houses; white flies, 10[illegible]; greenhouse leaf tiers, 81; chrysanthemum gall midge, 57 (practically all houses growing chrysanthemums); mealy bugs, 42; sow bugs, 12; and so on through a list of twenty-three pests or groups of pests, each greenhouse crop being attacked by its own particular pest.

The survey showed the use of several remedies by the greenhouse men for a particular pest. Many of these remedies are patent or trade preparations, some of which sell at rather exorbitant prices, and all of which depend upon a few basic compounds for their worth as insecticides. It seems evident that quite a saving would result to the growers if more attention was paid to the selection of insecticides and the timeliness of application. Orchard men of the state have learned this lesson and are now buying only the basic materials needed in their spray pro-

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grams and making the dilutions and mixtures in the orchard, saving in both money and time, and with the added security of having applied the right mixture at the right time.

BASIC MATERIALS USED IN FUMIGATION

Two basic materials are used in greenhouse fumigation: nicotine from tobacco, and hydrocyanic acid gas.

The nicotine from tobacco is used either from the tobacco plant itself in the form of a smudge made from the entire plant or some part of the tobacco plant; or a nicotine extract from the tobacco plant. In any case the nicotine is the killing agent, killing the insect through the breathing organs. Probably the cheapest form of nicotine to be used as a smudge is the entire or parts of the tobacco plant, though so-called "free" nicotine is successfully used as a smudge. The extract is usually found on the market in the form of nicotine sulfate which contains forty per cent nicotine, or "free" nicotine. The nicotine sulfate may be used for all sprays calling for nicotine and the "free" nicotine where a volatile nicotine is needed.

Hydrocyanic acid has been used for some time in greenhouse fumigation. This acid is a gas under ordinary conditions. It may be generated by placing either sodium or potassium cyanide in a solution of sulfuric acid. This method of securing hydrocyanic acid liberates a large volume of the gas in a comparatively short time and in greenhouse fumigation this heavy concentration at times caused considerable damage to the plants in the house.

Recently a material known as calcium cyanide has appeared on the market. This form of cyanide slowly undergoes a change in the presence of air liberating hydrocyanic acid gas and leaving a residue consisting mostly of air-slacked lime.

CALCIUM CYANIDE IN GREENHOUSE FUMIGATION

The use of this material as the source of hydrocyanic acid in greenhouse fumigation for the control of greenhouse insect pests has been developed by the Bureau of Entomology, United States Department of Agriculture in cooperation with the Bureau of Plant Industry, Pennsylvania Department of Agriculture.

In experimental work carried on in greenhouses in the vicinity of Philadelphia satisfactory control of aphids and white-fly and promising indications of control of other pests were obtained. This Bureau has sent out letters of inquiry to several greenhouse owners and managers to gather what their experience has been with the use of calcium cyanide. The replies indicate that with

but few exceptions the growers are getting good results with this material.

One grower suffered severe injury to sweet pea plants by an overdose of the material. Another grower made the mistake of doing the work in daylight. He, too, experienced injury to his plants.

Plants Killed or Injured by Cyanide. Asparagus plumosus, snap dragon, sweet pea and marguerite are often injured by very slight doses of cyanide and they should not be included in houses to be fumigated. Any other plants known to be especially susceptible to cyanide injury should be removed, if possible, from the house before fumigation.

Plants Successfully Fumigated With Cyanide. The experiments at Willow Grove, Pennsylvania, include fumigation of the following plants without injury, using as much as one fourth ounce dose to each 1000 cubic feet:

Acalypha, achyranthes, ageratum, anthericum, aster, begonia, calendula, carnation, centaurea, chrysanthemum, citrus (grape fruit), coleus, cuphea, **Dicentra spectabilis, Didiscus coeruleus, Dracena indivisa,** egg plant, ferns (Boston), **Ficus elastica,** freesia, fuchsia, gardenia, geranium, gladiolus, heliotropium, hydrangea, **Impatiens sultana,** ivy (English), larkspur, lantana, **Lilium giganteum,** myosotis, nasturtium, cattleya, cypripedium, laelia, kentia, pandanus, parsley, peach, pelargonium, pepper, petunia, **Primula obconica,** rose, salvia, schizanthus, **Vinca rosea, Vinca variegata,** wallflower.

Description of Calcium Cyanide. Calcium cyanide is a dark gray solid, resembling calcium carbide in many ways, and is found on the market in flake, granular and powdered form. Upon exposure to the air calcium cyanide undergoes a change, liberating hydrocyanic acid in the form of a gas and leaving a colored residue which is mostly lime. The hydrocyanic acid liberated is the killing agent, and when used in sufficient concentration it is a deadly poison to both men and other animals. There is a slight amount of acetylene gas given off at the same time, the odor of which serves as an indicator of the presence of the other gas.

Dosage to Use and Methods. Much attention must be given to the correct amount of the material to use to each 1000 cubic feet of greenhouse space. As has been stated, damage to the plants and serious loss will result if an overdose is used. The following points must be followed if loss is to be avoided and the insects killed.

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SIX POINTS WHICH MUST BE OBSERVED

1. Calculate accurately the cubic space in your greenhouse (See page 6)
2. Be sure your house is free from plants which are especially susceptible to injury from fumes of cyanide (See page 5)
3. Accurately weigh out the amount of material needed. Start with one-eighth (1/8) ounce to 1000 cubic feet. If your house is fairly tight this dosage will be quite enough. (See page 7)
4. Always start the fumigation about one hour after sundown—never before. Choose a still night.
5. Do not water the greenhouse for at least twenty-four hours before fumigation.
6. The temperature should be between 55 and 70 degrees Fahr., and it should be a rising rather than a falling temperature. Falling temperatures produce moisture which collects on the plants and makes them more susceptible to injury.

SIX ESSENTIALS IN CYANIDE FUMIGATION

Calculation of Cubical Air Space in the Greenhouse. To calculate the number of cubic feet in a greenhouse the width is multiplied by the length and this by the average height. To get the average height add the lowest height and the highest height together and divide by two. To illustrate: If a house is six feet high at the lowest part when viewed from the end, and ten feet high

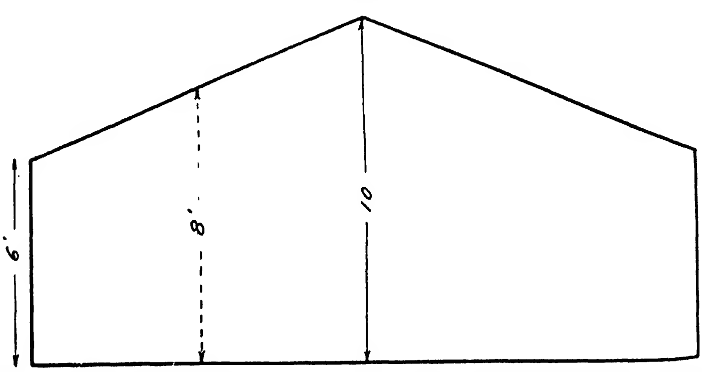

Fig. 1. Plan for getting average height of a greenhouse with sides of the same height

at the highest point when so viewed, the average height would be eight feet. (See Fig. 1)

Houses which have uneven heights on either side of the center may be calculated by finding the average height for each side and considering each side as separate houses for convenience of calculations. (See Fig. 2)

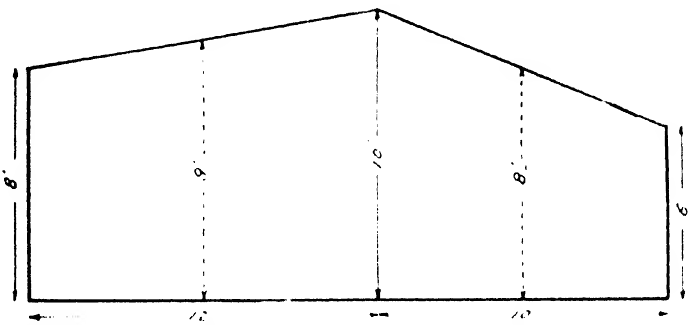

Fig. 2. Plan for getting cubical contents of a greenhouse with sides of uneven height

Preparing the Dose. Do not guess as to the required amount of material needed, make careful weighings wherever possible. After the required amount is weighed out, divide into several lots. To apply, simply scatter the material on the walks of the greenhouse. (See cover page). The material should be evenly distributed over the length of the walks of the house in order to get an even distribution of the gas. Only the center walk need be used in houses of 10 feet or less in width. Use two or more walks in wider houses.

Amount to Use: As stated before begin by using one-eighth ($\frac{1}{8}$) ounce to each 1000 cubic feet for the first fumigation. If this gives a kill, future fumigations should be with $\frac{1}{8}$ ounce to each 1000 cubic feet. If the kill is not complete, increase the amount to one fourth ($\frac{1}{4}$) ounce to each 1000 cubic feet. The tightness of the greenhouse is the reason for failure or success with the one-eighth ounce charge.

Time and Duration of Exposure. It has long been known that fumigation with hydrocyanic acid in greenhouses in daylight is accompanied by heavy loss to the plants so treated. Since the killing agent in calcium cyanide is hydrocyanic acid the usual night-time fumigation should be followed. The charge should be placed soon after sundown and the house kept closed until the following morning. A still night should be chosen since less gas

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will be lost from the greenhouse due to wind and circulation of the air.

After the cyanide has been placed on the walks leave at once and close the doors.

After a few hours the concentration of the gas is slight, and some growers enter the house once or twice during the night to observe the thermometers to guard against a fall of temperature. Airing is not necessary the following morning because of the weakness of the concentration, and most of the gas will have been dissipated.

Temperature and Moisture. The presence of moisture on plants increases the likelihood of injury to them when fumigated with hydrocyanic acid. There is always enough moisture present in a greenhouse to bring about the liberation of the gas from the calcium cyanide, hence there is no need to add more on this account. The temperature should be between 55 and 70 degrees Fahr., and should be maintained at an even temperature since falling temperatures produce moisture, thus producing a condition favorable for injury.

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CALCIUM CYANIDE AS A FUMIGANT FOR ORNAMENTAL GREENHOUSE PLANTS

C. A. WEIGEL,

Associate Entomologist, Tropical and Subtropical Fruit Insect Investigations, Bureau of Entomology

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During the last few years the chemical compound known as calcium cyanide has attracted considerable attention from entomologists because of its promising insecticidal properties. More recently it has assumed a unique place in greenhouse insect warfare as a convenient source of hydrocyanic-acid gas for fumigating purposes. It is now available on the market in the form of dust and coarse and fine granules. These seem well adapted for greenhouse use; the dust is more finely ground and gives off the gas more rapidly than does the granular form.

Unlike fumigation with potassium or sodium cyanide by the "pot method," the use of calcium cyanide does not require jars or the addition of sulphuric acid and water to generate the gas. On exposure to the air, calcium cyanide slowly reacts with the moisture of the atmosphere and gives off hydrocyanic-acid gas. With the quantity commonly used this reaction continues for several hours. Gas generated by the pot method is given off almost instantly and reaches its maximum concentration within a very few minutes, and the fumigation normally requires only one hour's exposure. Calcium cyanide, on the other hand, because of its gradual liberation of the gas, gives a lower concentration, requiring exposures lasting from three hours to over night.

Hydrocyanic-acid gas, whether produced from calcium, sodium, or potassium cyanide, is a cheap and effective insecticide, useful for controlling aphids, thrips, white flies, and other insects occurring on plants grown under glass. It should be remembered, however, that

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this gas is very poisonous and that unless it is handled with proper caution its use may cause disastrous results to the plants and the operator. Hydrocyanic-acid gas is colorless and has the odor of peach pits.

PREPARATION OF GREENHOUSE FOR FUMIGATION

Before attempting to fumigate, it is essential that the greenhouse be made as nearly gas tight as possible by replacing broken glass and closing tightly all ventilators, doors, or other openings that are not to be used during the exposure. At times it may be necessary to fumigate on hot nights in the summer months, or to employ a dosage heavier than usual, as in the control of scale insects on orchids, palms, rubber plants, aspidistra, and other plants which can tolerate a higher concentration of gas; in either case it may not be desirable to run the exposure throughout the night.

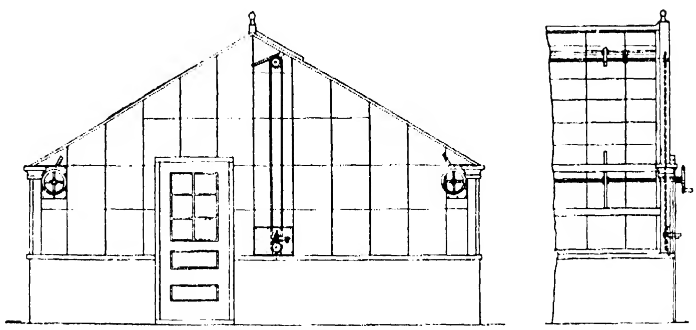

FIG. 1.—Arrangement for opening roof and side ventilators from outside the end of the greenhouse

Because of the high concentration used under these conditions, it is safer not to enter the greenhouse until it has been ventilated. To avoid possible danger, a greenhouse can be aired at the end of the fumigation by having the side and roof ventilators arranged so that they can be operated from the outside. There are various ways in which this can be accomplished. A method recently devised by the writer and used successfully in the greenhouses of the United States Botanic Garden is to disconnect the gears by which the ventilators are operated from within and attach extensions to the main shafts of the roof and side ventilators, so that they project through the end of the greenhouse. The control wheel for each side ventilator is then attached to its extension. In case of the roof ventilator a spare control may be installed on the outside of the greenhouse, at the end, as shown in Figure 1. For greenhouses several hundred feet long alternate sections of the ventilators may be disconnected and operated from the sides of the house by removing the local control and attaching to the gear a piece of gas piping or half-inch round iron shafting. This shafting should extend through the side of the house and have the

control wheel attached to its free end (fig. 2). In a method devised by Sasseer and Borden an arm (*a* or *b*, fig. 3) is attached to the central ventilator shaft, after disconnecting the operating gear of the roof ventilators. This arm can be controlled by a cord or wire which extends through the side of the greenhouse (fig. 4.) If only

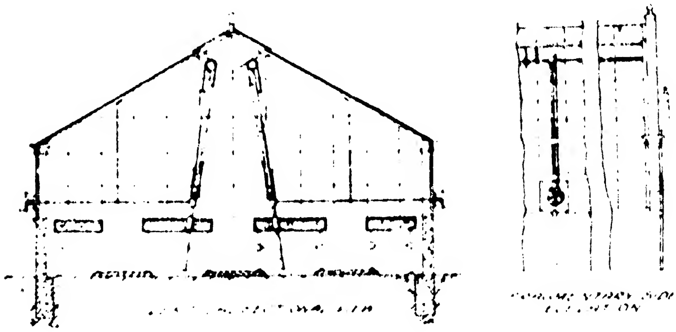

FIG. 2.—Arrangement for opening roof ventilator from without, ends [illegible] of the greenhouse

one ventilator can be opened, it is preferable that it be the one on the roof of the greenhouse. This method may be modified by extending the main shaft through one end of the greenhouse, as previously explained, and attaching to its free end an elbow connection, making with it a right angle and bearing a pipe extension several feet long. After disconnecting the controls, the ventilators can be operated from the outside by raising the pipe extension enough to lift the ventilators a few inches. A piece of wooden studding placed on end may be used to support the pipe extension while the ventilators are raised.

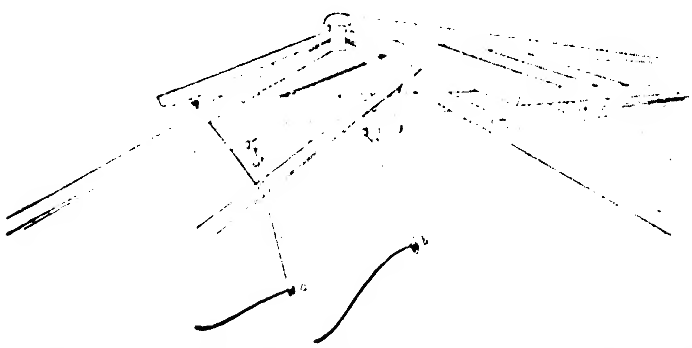

FIG. 3.—Methods of attaching rod and cord (*a*, *b*) to ventilator shaft of a greenhouse so that the ventilator can be opened from the outside after fumigation. (Sasseer and Borden.)

The gears on the side ventilators may be disconnected so that the sashes may be opened by merely lifting them from the outside, and propped with any convenient support until the ventilation is complete.

USE OF CURTAINS TO SEPARATE PORTIONS OF A RANGE

In the open-range type of greenhouses where miscellaneous crops are grown, it is not always necessary or desirable to fumigate the

FIG 4.—Interior of greenhouse Arrangement of ventilator arm and attached cord to enable operation from the outside

whole series of houses at one time or with the same dosage. For example, when a particular insect is localized on one crop it may be unnecessary to fumigate the whole range, or it may be undesirable to do so when plants growing in the adjoining sections are likely to

be injured by the dosage used. In such cases the house or portion to be fumigated may be separated from the others by the use of canvas or muslin curtains (fig. 5). These may be cut in 50-foot lengths to permit easier handling. The width should be such that the curtains when hung will make a partition from the roof to the ground. The same object may be attained by constructing a temporary partition of sash, resting on the ground and nailed to the eaves plate, or by using oiled or tarred paper fastened to upright wooden supports. When either of these devices is employed in mild weather the ventilators in the adjoining portion may be left open, or raised so far that any gas coming from the fumigated houses will soon escape. In extremely cold weather, of course, this can not be done, because he plants might be chilled if the ventilators were left open.

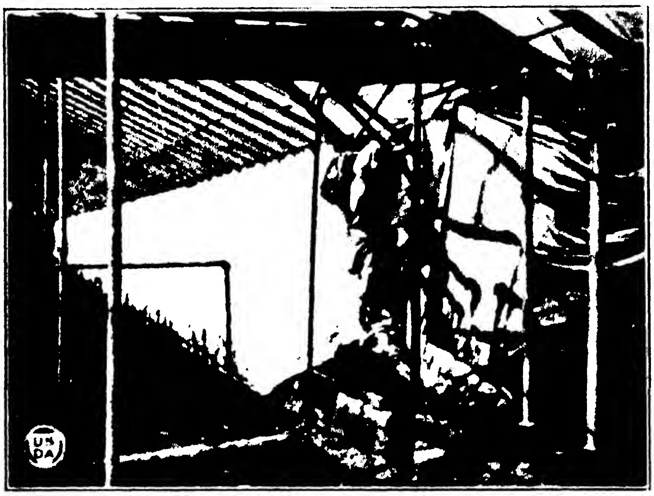

FIG. 5.—Muslin curtain [illegible] greenhouse during fumigation. (Weigel and Doucette.)

HOW TO DETERMINE THE CUBICAL CONTENTS OF A GREENHOUSE

In estimating the cubical contents of a greenhouse, it is not necessary to deduct the space occupied by the benches and pots.

To determine the cubical contents of a greenhouse of rectangular ground plan, as nearly all greenhouses are, first find the area of the end of the house and multiply it by the length. If all the dimensions used are expressed in feet, the result will be the volume in cubic feet. Upon the shape of the end of the greenhouse depends the method of computing its area. Almost without exception the end of a greenhouse has a horizontal base and vertical sides. The height of each side and the height of the ridge above the floor are dimensions which must be known. In addition, if the sides are of the same height, that is, if the greenhouse is of the "even-span" type, the width of the house should be multiplied by the average height, or half the sum of the height of one side and the height of the ridge. If the sides are

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unequal, it will be necessary to find the horizontal distance from the foot of each side to the foot of a vertical line through the ridge, dividing the end into two parts. The area of each part can be found by multiplying its width by its average height, or half the sum of its two vertical sides, one of the two being always the height of the ridge.

For example, in the case of an even-span greenhouse 20 feet wide, 5 feet high at the eaves, 10 feet high at the ridge and 100 feet long (fig. 6), we have for the area of the end $\frac{10+5}{2} \times 20 = 150$ square feet; and for the cubical contents, $150 \times 100 = 15{,}000$ cubic feet.

To determine the cubical contents of a greenhouse having unequal sides, a three-quarter span greenhouse 24 feet wide, 100 feet long, and 12 feet high (fig. 7) will serve as a good example. Here the end of the house is divided into two areas, one (*a*) having a base 6 feet long and sides 12 feet and 8 feet high, and the other (*b*) a base

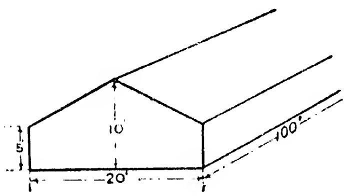

FIG. 6.—Diagram illustrating method of computing cubical contents of an even-span greenhouse

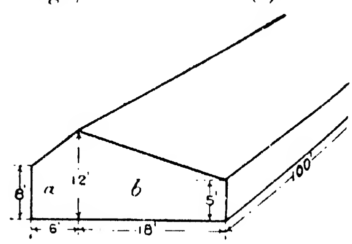

FIG. 7.—Diagram illustrating method of computing cubical contents of three-quarter, or other uneven, span greenhouse

18 feet long and sides 12 feet and 5 feet high. For the first area we have

$$\frac{12+8}{2} \times 6 = 60 \text{ square feet,}$$

and for the second,

$$\frac{12+5}{2} \times 18 = 153 \text{ square feet.}$$

For the two areas we have a total of 213 square feet. Multiplying 213 by 100, the length of the greenhouse, we find that it contains 21,300 cubic feet.

QUANTITY OF CALCIUM CYANIDE TO USE

In cyanide fumigation it is convenient to state the dosage or rate in terms of ounces of calcium cyanide for each 1,000 cubic feet of air space in the house. At the quarter-ounce rate the even-span greenhouse (fig. 6) having a capacity of 15,000 cubic feet would require 15 quarter ounces or 3¾ ounces of calcium cyanide. The three-quarter-span house (fig. 7) with a capacity of 21,300 cubic feet would require 21 quarter ounces or 5¼ ounces of calcium cyanide. The correct dosage for a particular purpose depends on the tightness of the house, the kind of insect to be controlled, and the susceptibility of the plants to injury.

In a relatively air-tight house an overnight fumigation at the quarter-ounce rate is effective in controlling adult white flies and

the various species of aphids (see Table 1) which attack roses, carnations, chrysanthemums, and similar floral crops, with little or no injury to the plants. Should this dosage prove ineffective, because the house is too leaky to retain a sufficient concentration of the gas the rate can be gradually increased in succeeding fumigations to one-third ounce or one-half ounce, or until a dosage rate is found which will control the insects without injuring the plants. In no case is fumigation at rates in excess of 1 ounce recommended unless the florist first tries it out on a small scale under his particular conditions.

TABLE 1.—*Percentage mortality of various greenhouse insects obtained by the use of calcium cyanide granules at the rates indicated*

Insect	Dosage per 1,000 cubic feet	Exposure	Temperature at beginning of experiment	Humidity at beginning of experiment	Number of specimens	Per cent of mortality
	Ounces	*Hours*	*°F.*	*Per cent*		
Greenhouse whitefly, Trialeurodes vaporariorum Westw.	1/4	14	59	83	[illegible]	100
Thrips (adult)	1	10	69	90	6[illegible]	8[illegible]
Greenhouse leaf tyer (moth), Phlyctaenia rubigalis Guen.	1/2	4	6[illegible]	65	52	100
Aphids:						
Brown chrysanthemum aphid, Macrosiphoniella sanborni Gill.	1/4	12	72	86	1,126	100
Green chrysanthemum aphid, Rhopalosiphum rufomaculata Wils.	1/4	13	55	76	1,130	100
Peach aphid on carnation, Myzus persicae Sulz.	1/4	13	65	84	880	65
Rose aphid:						
Macrosiphum sp.	1/4	12	72	86	633	100
Myzaphis sp.	1/4	12	66	90	3,000	100
Nasturtium or bean aphid, Aphis rumicis L.	1/4	15	69	6[illegible]	[illegible]	100
Sweet pea aphid, Illinoia pisi Kalt.	1/4	13	55	76	2[illegible]8	98.7
Anuraphis helichrysi Kalt.	1/4	1[illegible]	63	89	264	65.1
Mealybugs:						
Citrus mealybug, Pseudococcus citri Risso	1/2	17	71	52	118	[1] 96.4
	5/8	13	72	55	196	94.3
Palm mealybug, Pseudococcus nipae Mask.	1/2	17	68	42	113	96.3
	3/4	17	70	59	158	96.2
Baker's mealybug, Pseudococcus maritimus Ehrh.	1/2	4	65	65	50	0
Greenhouse orthezia, Orthezia insignis Doug.	1/2	12	73	85	29	100
Azalea bark scale, Eriococcus azaleae Comst.	3	13	70	64	329	99.7
	3	16	64	78	50	100
Scale insects:						
Florida red scale, Chrysomphalus aonidum Linn.	1/2	17	68	42	90	97.8
	3/4	15	70	50	355	100
Morgan's scale, Chrysomphalus dictyospermi Morg.	1 1/2	6	70	64	550	100
Orchid scale, Chrysomphalus biformis Ckll.	4	14	61	49	176	100
Boisduval's scale, Diaspis boisduvalii Sign.	1	12	66	85	654	100
Proteus scale, Parlatoria proteus Curt.	1	13	63	82	382	[1] 98.1
					215	[2] 23.2
Hemispherical scale, Saissetia hemisphaerica Targ.	1/2	17	68	42	21	94.4
	3/4	16	69	67	75	100
Purple scale, Lepidosaphes beckii Newm.	2 1/2	14	71	52	200	97.5

[1] Young. [2] Adult.

Table 1[1] gives the dosage rates of calcium cyanide that have been found, in recent experiments, to kill some of the insect pests frequently encountered in greenhouses. Before fumigation is undertaken, however, Table 3 should be consulted to ascertain the rate or

[1] The data presented in the tables represent actual results of experimental tests under the conditions stated, and are not intended as definite recommendations. Differences in dosages and in length of exposure are intended to suggest the probable range of conditions under which a given fumigation might be expected to be safe or effective. For example, in the summer the duration of a fumigation may be restricted to from 3 to 10 hours, whereas in the winter months it might last from 10 to 15 hours.

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dosage that particular plants can tolerate with little or no injury. If this dosage is less than that indicated in Table 1, of course, complete control can not be expected with one fumigation, as the adults, which are more resistant, will survive and continue to produce young. It will therefore be necessary to repeat the fumigation at frequent intervals until the infestation is eradicated.

HOW TO APPLY CALCIUM CYANIDE

After determining how much calcium cyanide is necessary, weigh out the required quantity and place it in a wide-mouthed bottle or other container. Then scatter evenly on the surface of the center walk or path (fig. 8), beginning at the far end and, walking backward, working toward the door. A convenient container for scattering calcium cyanide may be made from a baking-powder can by puncturing holes in the cover from the inside, using a 10-penny nail. A wide-mouthed glass jar with a perforated metal top can be used instead, and the glass jar enables the operator to watch the rate of distribution. Do not place the cyanide in the can or jar until ready to fumigate. Because calcium cyanide gives off gas when exposed to the air, the container in which it is stored should be kept tightly closed, and the quantity set apart for a given fumigation should be kept in a stoppered bottle or other secure container until about to be used. When spreading the material, be careful that none of it comes in contact with the plants. For larger greenhouses divide the materiel equally and scatter on two or more walks, depending on the width of the house. In such cases it is safer for one not to fumigate alone, but to have an operator for each path in which the calcium cyanide is to be applied.

Calcium cyanide must not be placed in piles, as is customary in fumigation with nicotine or tobacco, because the atmospheric moisture could not readily reach the inner portion of the pile, and probably not all the gas would be given off. Moreover, the gas evolved would not be evenly diffused throughout the greenhouse. With a little practice the operator soon learns how to scatter the material evenly from end to end of the greenhouse.

WHEN AND HOW OFTEN TO FUMIGATE

Greenhouse fumigation should be done only after dark and should not begin earlier than one hour after sunset. It should be done on still nights, because high winds may reduce the concentration by drawing the gas out of the greenhouse. Fumigation in the winter should preferably be done in mild weather and not on extremely cold nights, when it might be difficult to maintain proper temperatures. Hot, humid nights should also be avoided, because the temperatures can not be lowered to the required limit. Temperatures ranging between 60° and 70°F. are most desirable.

The frequency of fumigation depends on the kinds of insects to be controlled and the proportion killed with one exposure. If a trial fails to give satisfactory results, fumigation should be repeated. When greenhouses containing an assortment of plants were fumigated with sodium cyanide, small dosages were found necessary Fumigation with such dosages killed only larvæ of scale insects, the adults and first larva stages of the greenhouse white fly, and most of the aphids. Moreover, the eggs and pupæ of most greenhouse insects

offer considerable resistance to hydrocyanic-acid gas and overlapping of broods frequently occurs. For these reasons several fumigations at intervals of a week or 10 days are often necessary in controlling such insects without injury to the plants. Data from experiments

FIG. 8.—Method of distributing calcium cyanide by means of a bottle with perforated cap

thus far conducted with calcium cyanide show that a satisfactory control of scale insects may be had by several fumigations at short intervals. Successive fumigations are very useful, even though no marked infestations exist, and are also a safeguard against sudden outbreaks.

Box fumigation may be done at any time, except that the plants must be shaded for at least a short time before and for a longer period after treatment. Immediate exposure to light, and particularly to bright sunlight, is very injurious to plants, especially palms and ferns, that have been fumigated in a box.

LENGTH OF EXPOSURE

Mention was made on page 1 of the gradual liberation of gas from calcium cyanide, which makes it well suited for long or overnight exposures. Recent experiments in a tight fumigation box with four species of aphids have confirmed this conclusion, as shown by the results presented in Table 2. It is evident that in all cases, even at the lowest dosage rates, exposures lasting overnight gave virtually complete control of the aphids. The relatively low control resulting from an exposure of one hour to various dosage rates up to three-fourths of an ounce of calcium cyanide indicates that one hour is too short a time to permit an effective concentration of the gas. In other experiments,[2] not presented in this article, very finely ground calcium cyanide gave a mortality of 82.7 per cent of the green chrysanthemum aphid (*Rhopalosiphum rufomaculata*) with an exposure of only one hour. In these experiments it became evident that calcium cyanide dust gives off the gas more rapidly than the granules, and that certain species of aphids are more susceptible to the gas than others. Beginning with a minimum dosage of one-half ounce and exposures lasting three hours or longer, a satisfactory control was obtained. Such results can, of course, be obtained only in cases where the greenhouses and fumigation boxes are tight enough to retain an effective concentration of the gas during the fumigation.

TABLE 2.—*Degree of control of four species of aphids which resulted from box fumigation with calcium cyanide, with varying dosages and exposures*

Dosage per 1,000 cubic feet	Exposure	Temperature	Humidity	Mortality of— Nasturtium aphid [1]	Rose aphid [2]	Black chrysanthemum aphid [3]	Green chrysanthemum aphid [4]
Ounces	*Hours*	*°F.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1/16	16	69	59	99.6	99	100	100
1/8	15	72	49	99.6	100	100	100
1/4	1	60	78	5	15.3	10.8	2.5
	6	66	66	9	20.7	56.2	78.2
	15	67	58	98.5	91.9	100	100
3/8	15	71	52	100	100	100	100
1/2	1	69	67	24.3	13.5	19.1	17.8
	3	69	81	52.1	41.4	79	85
	6	62	64	73.6	80	91.5	85.3
	15	63	69	100	100	100	100
3/4	1	68	58	52.4	69.2	71.7	77.7
	15	78	53	100	100	100	100

[1] *Aphis rumicis* L.
[2] *Myzaphis* sp.
[3] *Macrosiphoniella sanborni* Gill.
[4] *Rhopalosiphum rufomaculata* Wils.

The foregoing information is very important and useful when applied to the fumigation of crops where there is doubt as to the advisability of subjecting plants to a long exposure on hot nights, or where heavier dosages are employed, as in the case of orchids. Under such

[2] Jour. Econ. Ent., vol. 18, No. 1, pp. 137-141, Feb., 1925.

conditions the ventilators may be raised or the fumigation box opened at the end of three hours and the house or box aired. The quantity of gas given off by any residual cyanide would after airing be negligible.

VENTILATION AFTER FUMIGATION

In fumigating with sodium cyanide short exposures, such as one or two hours, with a dosage ranging from one-half ounce to 1 ounce of the cyanide per 1,000 cubic feet, appeared to be more satisfactory than a lower strength of gas over night. The short exposures had the additional advantage of permitting the greenhouse to become thoroughly aired previous to the rising of the sun. Recent tests with calcium cyanide at such low dosages as one fourth ounce made in large commercial houses in Washington, D. C., and in eastern Pennsylvania, have shown that ventilation is rarely necessary, except in new and exceptionally air-tight greenhouses, since little if any of the gas remains in the ordinary type of house after over-night fumigation. In any case, however, if the odor of gas is strong, the greenhouses should be thoroughly aired the following morning, before the sunlight strikes the plants.

BOX FUMIGATION

Florists and nurserymen will find it very advantageous to have a fumigation box for the following purposes: (1) In preliminary tests, to determine the quantity of gas that plants can withstand without injury in the several stages of growth; (2) to rid individual or potted plants of insects when an isolated infestation is discovered, and thus to avoid the frequently used costly and laborious hand scrubbing of the plants; (3) when it is unnecessary to fumigate an entire greenhouse. Its use is almost indispensable for such plants as orchids, palms, aspidistra, and ferns, and has an advantage in that it may be used in the daytime; whereas house fumigation can be performed with safety after dark only. Moreover, in box fumigation such factors as leakage, light, moisture, and temperature, which influence the success of the treatment, vary less than in greenhouses.

Plants to be fumigated in a box in the daytime should remain in the box with the door nearly closed, so as to prevent direct rays of light from reaching them for at least one hour before the gas is generated. After the completion of the exposure, plants should be shaded from bright sunlight for at least four hours. For shading, a closely constructed slat house or potting shed is suitable.

CONSTRUCTION OF A FUMIGATION BOX

The capacity of the box will naturally depend on the size of the establishment and the amount of fumigating to be done. Normally a box 5 feet square by 8 feet high, plans of which are given in Figure 9, is adequate for the average floral establishment.

For the framework use 2 by 4 inch material, and for the double walls, roof, and floor use 2-inch tongue-and-groove pine sheathing, or matched lumber, with heavy building paper or wall board between. The material of the inside walls should run horizontally and that of the outside walls vertically. The door should be built somewhat like that of a refrigerator and swing on three heavy hinges, the edges closing against a felt or rubber seat. Similar precautions should be

taken for the casings of the ventilator in the roof, in order to make it air-tight. If the volume of business warrants it, the walls may be made of concrete, or glazed hollow tile laid in cement. A series of adjustable shelves, as shown in the plans, upon which the plants can be placed, permits a better diffusion of the gas around the material to be fumigated. The suction fan referred to in the plans is not absolutely necessary, except when the box is built within a com-

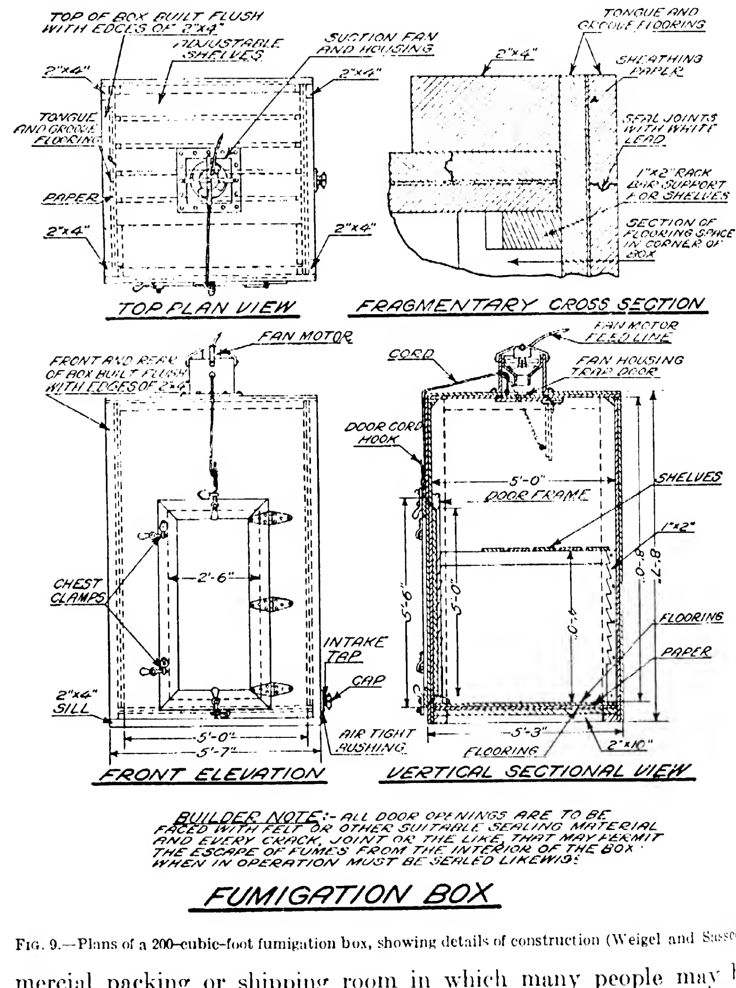

FIG. 9.—Plans of a 200-cubic-foot fumigation box, showing details of construction (Weigel and Sasscer)

mercial packing or shipping room in which many people may be working, or when time is a factor; in other cases the ordinary ventilator is a sufficient opening to permit the escape of the gas.

Fumigation boxes should not remain exposed to the weather, as they will soon warp and become unfit for use. For this reason it is advisable also to keep doors and ventilators closed when the box is not in operation.

EFFECTS OF WEATHER AND OTHER CONDITIONS ON FUMIGATION

Among the various factors which influence the effectiveness of calcium cyanide as a fumigant are temperature, humidity, moisture, light, and high winds.

Temperatures ranging from 60° to 70° F. are preferred, because the insects become inactive at low temperatures and are then more resistant to the gas, and if the temperature drops below 55° F. moisture may appear on the leaves, thus increasing the risk of injury to the plants. High temperatures should be avoided, because succulent tender growth under such conditions is particularly susceptible and is likely to be injured.

Humidity or atmospheric moisture is an essential factor in releasing the hydrocyanic acid gas from the calcium cyanide. The results of the experiments made thus far indicate that relative humidities of from 40 to 70 per cent are sufficient for this purpose. Extremely high humidity, especially if accompanied by a temperature above 70° F., a condition that often exists on a muggy night, increases the risk of injury.

The presence of excessive moisture in the greenhouse reduces the concentration of the gas and is therefore undesirable. The plants should not be watered just prior to fumigation. The walks or paths may be damp, but no standing water should be present, as the gas, which is soluble in water, would be taken up by it. When the calcium cyanide is sprinkled on wet walks complex reactions take place which reduce the normal quantity of hydrocyanic-acid gas given off, thus impairing the effectiveness of the fumigation.

To avoid the decidedly injurious effect of sunlight on the fumigated plants, greenhouse fumigation should be attempted only after sunset and in the dark. The internal conditions and active growth of the plants during daylight or while exposed to sunlight renders them more susceptible to the effects of the gas. The breathing pores, or stomata, are also likely to permit the entrance of more gas into the tissues than they would absorb in the dark. Shading the plants, especially palms and ferns, from direct sunlight for a few hours after fumigation is of value in reducing the risk of injury and often prevents the occurrence of burning.

Still nights are preferable for fumigation, because high winds or strong currents of air tend to draw the gas out of any greenhouse which is not airtight and thus to prevent effective fumigation.

PRECAUTIONS

Do not guess at the cubical contents of the greenhouse or the quantity of cyanide to be used.

Fumigate greenhouses at night only. Box fumigation, however, may be done during the day.

Fumigate at temperatures above 55° F., preferably between 60 and 70° F.

Keep the cyanide away from people unacquainted with its poisonous nature and see that it is properly labeled. Avoid handling it more than necessary, and wash the hands after using.

Stay out of the greenhouse during fumigation. Tightly close the house and ventilators. Post warning signs before fumigating. Do not attempt to fumigate a large greenhouse alone.

If the greenhouse to be fumigated is near, or attached to, a dwelling the occupants should leave the house until the fumigation has been completed and thorough ventilation has rendered the premises safe.

GUIDE TO GREENHOUSE FUMIGATION

Table 3, which is offered as a guide to those desiring to employ calcium cyanide for controlling greenhouse insects, is based on the results of the experiments conducted thus far at the rates indicated. Temperature and humidity readings were made at the beginning of each fumigation test. As is evident in this table, certain plants are more susceptible than others to injury from hydrocyanic-acid gas. For example, such plants as *Asparagus plumosus* and *A. sprengeri*, Wandering Jew, snapdragon, sweet pea, chrysanthemum, marguerite, heliotrope, ageratum, and rose will not tolerate as high a concentration of gas as ferns, palms, rubber plants, orchids, and aspidistra. It is imperative that this fact be borne in mind when a greenhouse or range of houses containing a miscellaneous assortment of plants is to be fumigated.

In the case of most varieties of plants, it is the newest growth that may be damaged, particularly the young and tender tips and buds; the mature growth is less likely to show injury. Because of this fact, fumigating for the control of insects at a time when there is a minimum of succulent growth on the plants will materially reduce the risk of injury. Where the infestation is so heavy as to require the immediate treatment of plants which are easily burned, the florist must choose between the loss which would result from continued injury by insects and that caused by fumigation, the latter being usually only temporary and speedily outgrown.

TABLE 3.—*Results of fumigation with calcium cyanide in greenhouses and fumigation boxes*

[Plants designated by * were fumigated in a box]

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Greenhouse temperature	Greenhouse humidity	Effect of treatment on plants
	Ounces	*Hours*	° *F*	*Per cent*	
Abelia grandiflora	3/4	12	73	92	No burning.
Abutilon eclipse	3/4	12	73	92	Do.
Acalypha godsefliana	1	10	69	90	Do.
Acalypha wilkesiana	1	10	69	90	Do.
Ageratum sp	1/4	12	61	90	Do.
Do	1/2	14	74	61	Do.
Ageratum dwarf	1/2	12	73	93	Slight burning.
Allamanda hendersoni	3/4	12	73	92	Do.
Alternanthera	2	1	68	83	Do.
*Amaryllis (Hippeastrum sp.)	2 1/2	16	86	56	No burning.
Anthericum liliago variegatum	1/2	14	74	61	Do.
Aralia sieboldi (Fatsia japonica)	3/4	12	73	92	Do.
*Artillery plant (Pilea muscosa)	1/4	16	69	59	Moderate injury
*Do	1/8	15	72	49	Severe injury.
Asparagus plumosus	1/4	13	63	84	Severe burning.
*Asparagus sprengeri	1/8	15	72	49	Trace burning on new tips.
Aspidistra lurida	1	15	69	63	No burning
Aspidistra lurida variegata	1	15	69	63	Do.
China aster (Callistephus)	1	10	69	90	Very slight
*Azalea indica	1/2	6	63	71	No burning.
*Do	3	16	64	38	Slight spotting of tips.
Banana (Musa)	3/4	12	73	92	No burning.
Begonia sp	3/4	12	73	92	Do.
Begonia sp	2	15	71	60	Do.
Bleeding heart (Dicentra spectabilis)	1	10	69	90	Do.
Blue lace flower (Trachymene caerulea)	1/4	1	61	89	Do.

TABLE 3.—*Results of fumigation with calcium cyanide in greenhouses and fumigation boxes*—Continued

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Greenhouse temperature	Greenhouse humidity	Effect of treatment on plants
	Ounces	*Hours*	*F.*	*Per cent*	
Blue sage (Salvia azurea)	3/4	12	73	92	No burning.
Brugmansia (Datura suaveolens)	2	1	68	83	Do.
Buddleia forresti	3/4	12	73	92	Severe injury.
Buddleia variabilis	3/4	12	73	92	Do.
Buxus sempervirens var. suffruticosa	3/4	12	74	92	No burning.
Calla (Zantedeschia)	1/4	14	70	88	Do.
Camphor (Cinnamomum camphora)	1/2	11	63	98+	Do.
Cape-jasmine (Gardenia florida)	1/2	11	63	98+	Do.
Carnation (Dianthus caryophyllus)	1	14	74	61	Do.
Caryopteris incana (blue spirea)	1	12	70	91	Do.
Cereus (night-blooming)	1	11	63	98+	Do.
Chrysanthemum sp.	1/4	10	61	90	Slight injury.
Do.	1/4	13	[illegible]	56	No burning.
*Do.	1	15	[illegible]	64	Severe injury.
Cissus discolor	1	12	73	93	No burning.
Coleus sp.	1/2	11	63	98+	Severe injury.
Do.	1	14	69	90	No burning.
*Do.	1	6	69	51	Do.
Cosmos	3/4	12	73	92	Do.
Cuphea ignea (cigar plant)	1	10	69	90	Do.
Cyclamen persicum (in flower)	1/2	13	61	89	Do.
Cyclamen latifolium	1	14	69	90	Do.
Cyperus alternifolius (umbrella sedge)	3/4	12	73	92	Do.
Do.	2	1	68	83	Do.
Delphinium (annual larkspur)	1	10	69	90	Do.
Dracaena (Cordyline indivisa)	2	15	71	68	Do.
Dusty miller (Centaurea cineraria)	1	10	69	90	Do.
Do.	2	1	68	83	Slight injury.
Elephant's ear (Colocasia esculenta)	2	1	68	83	No burning.
Evonymus japonicus	3/4	12	73	92	Do.
Evonymus radicans	3/4	12	72	92	Do.
Evonymus sieboldiana	3/4	12	72	92	Do.
Evonymus variegata [illegible]	3/4	12	73	92	Do.
Ferns:					
*Adiantum sp. (maidenhair fern)	3/4	16	64	67	Do.
Do.	[illegible]	15	66	53	Slight injury (old growth).
Cyrtomium falcatum (holly fern)	1/4	14	70	83	No burning.
Cyrtomium rochfordianum	1/4	14	70	83	Do.
Dryopteris [illegible] (wood fern)	1	14	69	90	Do.
Nephrolepis sp.	1	14	69	90	Do.
Nephrolepis exaltata bostoniensis (Boston fern)	3/4	14	70	83	Do.
Do.	1/2	11	57		Do.
*Nephrolepis [illegible]	1/4	16	60	67	Do.
Pteris spp.	1/4	14	70	83	Do.
Ficus elastica	1	11	69	90	Do.
Ficus pandurata	1	14	69	90	Do.
Forget-me-not (Myosotis)	1/2	12	73	93	Do.
Freesia	1/4	14	70	83	Do.
Fuchsia	1	10	69	90	Do.
Geraniums:					
Pelargonium sp.	1/2	14	69	90	Do.
Lady Washington (P. domesticum)	1/2	14	69	90	Do.
Rose (P. graveolens)	1/2	11	63	98+	Do.
Gladiolus	1/4	1	61	89	Do.
Gloxinia	1/2	11	63	98+	Severe injury.
Grape, Concord (Vitis)	3/4	12	73	92	No burning.
Guava (Psidium)	1/2	11	63	98+	Slight injury.
Heliotrope (Heliotropium peruvianum)	1/2	14	69	90	No burning.
Hibiscus cooperi	1/2	12	70	91	Do.
Hydrangea otaksa	1/2	12	70	91	Do.
Ivy (Hedera helix)	3/4	12	73	92	Do.
Jasminum:					
Grand Duke	1	14	74	61	Do.
*Grandiflorum	1/2	16	69	59	Tips burned slightly.
*Multiflorum	1	15	63	55	Do.
Nudiflorum	3/4	12	73	92	Do.
Primulinum	3/4	12	73	92	No burning.
Jerusalem cherry (Solanum pseudo-capsicum)	1/2	11	63	98+	Do.
Justicia rosea	3/4	12	73	92	Do.
Kerria japonica	3/4	12	73	92	Do.
Kudzu vine (Pueraria thunbergiana)	2	1	68	83	Do.
Lavender (Lavendula officinalis)	3/4	12	73	92	Very slight tip burning.
Lantana camara	1/2	12	73	93	Very severe burning.

TABLE 3.—*Results of fumigation with calcium cyanide in greenhouses and fumigation boxes*—Continued

Name of plant	Cyanide per 1,000 cubic feet of space	Length of exposure	Greenhouse temperature	Greenhouse humidity	Effect of treatment on plants
	Ounces	*Hours*	*° F.*	*Per cent*	
Lantana camara	½	12	73	93	No burning.
Lantana sp	½	13	61	89	Do.
Lemon verbena (Lippia citriodora)	½	13	61	89	Do.
Lilium giganteum (Giant lily)	½	14	74	61	Very slight tip burning.[1]
Marguerite daisy (Chrysanthemum frutescens).	¼	13	63	84	Slight injury.
Do	¼	15	65	56	No burning.
Marigold (Calendula officinalis)	¼	13	61	84	Do.
Moonflower (Ipomœa grandiflora)	1½	1	72	75	Do.
Moonflower (Ipomœa tubiculata)	½	12	73	93	Very severe injury.
Night-blooming cestrum (Cestrum nocturnum).	2	1	68	83	Slight injury.
Oleander (Nerium oleander)	¾	12	73	92	No burning.
Orchid:					
Cattleya sp	1	14	69	90	Do.
Cypripedium (2 varieties)	1	14	69	67	Do.
Lælia sp	1	14	69	90	Do.
*Oncidium	½	15	68	42	Do.
Do	4	14	61	49	Slight injury.
Do	1	14			Severe injury.
Palms:					
Kentia sp. (Howea)	1	12	66	85	No burning.
Pandanus veitchi	1	14	69	90	Do.
Peristrophe	½	12	73	85	Do.
Periwinkle (Vinca)	½	14	69	90	Do.
Petunia	1	6	64	91	Slight injury.
Pittosporum	½	11	63	98+	No burning (older leaves).
Plumbago capensis	½	11	63	98+	Slight injury.
Plumbago capensis alba	½	11	63	98+	Do.
Poinsettia (Euphorbia pulcherrima)	¾	12	73	92	No burning.
Primula obconica	¼	14	59	83	Do.
Rose:					
America	⅛	14	63	84	Do.
American Legion	¼	13	63	84	Do.
Butterfly	¼	13	65	80	Do.
Cecile Brunner	¼	15	65	80	Do.
Claudius Pernet	¼	12	72	95	Do.
Columbia	¼	12	66	90	Do.
Do	¼	14	57		Sepals burned.
Commonwealth	⅛	14	63	84	No burning.
Killarney (double white)	¼	13	63	79	Do.
Do	1	10	69	90	Do.
Premier	¼	9	65	86	Do.
Rosa odorata	½	12	72	91	Slight injury.
Sanchezia nobilis	¾	12	73	92	No burning.
Sansevieria zeylanica	¾	12	73	92	Do.
Santalum (sandalwood)	½	12	70	91	Do.
Scarlet sage (Salvia splendens)	¼	15	65	80	No burning (1 bloom).
Schizanthus pinnatus	¼	1	61	89	No burning.
Sensitive plant (Mimosa pudica)	½	11	63	98+	Severe injury.
Serissa foetida	¾	12	73	92	No burning.
Silk oak (Grevillea robusta)	2	1	68	83	Do.
Snapdragon (Antirrhinum majus)	¼	13	61	84	Do.
Do	¼	14	59	83	Severe injury.[2]
Snapdragon (Antirrhinum sp.)	½	14	69	90	No burning.
Spanish iris (Iris xiphium)	½	11	63	98+	Do.
Spider lily (Hymenocallis)	½	11	63	98+	Do.
Spiræa billiardi	¾	12	73	92	Do.
Spiræa lindleyana	½	12	70	91	Slight injury.
Do	¾	12	73	92	No burning.
Spiræa opulifolia	½	12	70	91	Do.
Spiræa vanhouttei	½	12	70	91	Do.
Sultan's balsam (Impatiens sultani)	½	12	73	93	Do.
Do	½	12	73	85	Slight burning.
Sweet olive (Olea fragrans)	¾	12	73	92	No burning.
Sweet pea (Lathyrus odoratus)	¼	13	54	76	Do.
Do	1	12	62	93	Slight injury.
Tapioca	¾	12	73	92	No burning.
Thistle (Onopordon)	¾	12	73	92	Do.
*Wandering Jew (Tradescantia)	⅛	15	72	49	Do.
Wax mallow (Malvaviscus arboreus)	½	12	70	91	Do.
Do	¾	12	73	92	Do.
Weeping willow (Salix babylonica)	½	12	70	91	Do.

[1] In flower. [2] Leaves spotted, flower sepals bleached.

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SECTION 3

FUMIGATION—BUILDING

Fumigation of Dwelling Houses

Hydrocyanic acid gas, as an effective fumigant for dwellings and warehouses to rid them of insect and rodent pests, has been in commercial use for the past twenty years. The earliest source of this gas was by generation from sodium or potassium cyanides by means of sulphuric acid. This method was found to be wasteful in that much time had to be spent in weighing out and combining the materials before the fumigation and in cleaning up afterwards.

The successful commercial use of liquefied hydrocyanic acid in the fumigation of citrus trees in California to replace the sodium cyanide method led to its application in the fumigation of enclosed spaces such as dwellings, ships, mills, and warehouses. The simplicity of application, the high concentration of gas, and the fact that there were no materials to be cleaned up after the fumigation were strong arguments in favor of its use in preference to sodium cyanide. Due to the difficulties of the distribution of a material such as liquefied hydrocyanic acid in such small quantities as would be necessary in the fumigation of dwelling houses, its use has never been developed either by the ordinary individual or the professional fumigator.

Experiments conducted in our technical laboratory indicated that by merely spreading out Cyanogas Calcium Cyanide in a thin layer on the floor it would yield a sufficiently high concentration of hydrocyanic acid gas to be effective in the fumigation of enclosed spaces. Tests to determine the concentrations obtained and the speed of evolution of the gas were carried out for the purpose of comparing the efficacy of Cyanogas "A" Dust, Cyanogas Granules, and liquefied hydrocyanic acid gas. Table I gives the results of these tests which took place under the following conditions:

1.—A fumigation chamber with a capacity of 750 cu. ft. was used in the tests. The chamber was not hermetically sealed.

2.—The Cyanogas was spread on newspapers in a layer one eighth of an inch thick.

3.—The Cyanogas was used at the rate of 1 lb. per 1000 cu. ft. of space, ¾ of one pound being used in the chamber.

4.—Comparison was made between the different grades of Cyanogas and an equivalent amount of liquefied

hydrocyanic acid, 4 ounces of liquid to 1000 cu. ft.

5.—Samples of the air in the room were taken at the end of the first hour and each half hour thereafter until the eighth hour and a final analysis at the end of 24 hours. The air was sampled alternately from the top and the bottom of the room.

One of the most interesting points is the fact that a more even concentration is obtained by the use of Cyanogas than in the case of liquefied hydrocyanic acid. In the beginning of the fumigation a low concentration is obtained by the use of Cyanogas, a decided advantage in that it gives a wide margin of safety. The person who is conducting the fumigation has ample time to leave the building. In the case of fumigations with sodium or potassium cyanide the highest concentrations are built up immediately as in the case of liquefied hydrocyanic acid gas.

TABLE I

CONCENTRATIONS OBTAINED DURING THE TESTS

Time	Temp.	Rel. Hum.	Concentrations of HCN in Parts Per Million: Cyanogas "A" Dust	Cyanogas Granular	Liquid HCN
1 hour	56	70	648	248	2224
1.5 hours	56	70	816	232	1536
2 "	56	70	976	248	1408
2.5 "	56	65	832	216	1080
3 "	57	65	944	304	680
3.5 "	58	65	832	304	592
4 "	59	60	848	344	592
4.5 "	60	60	760	368	528
5 "	62	60	704	432	488
5.5 "	64	65	640	456	472
6 "	64	65	640	496	472
6.5 "	64	65	600	496	464
7 "	63	70	600	520	456
7.5 "	63	70	600	520	456
8 "	62	70	592	560	448
24 "	56	85	48	320	000
Average concentration for first eight (8) hours			735.2	382.4	793.6

From time to time, various reports of house fumigations have been sent in by interested experimental workers. These indicate the success of Cyanogas in the control of household pests under diverse conditions. (Table II.)

TABLE II

CYANOGAS FUMIGATION OF DWELLINGS

DATE	PLACE	PEST	MATERIAL	RATE PER 1000 CU. FT.	EXPOSURE	EFFECT ON PEST	REMARKS
10/29/25	England (A. S. Barker)	Psocids House Flies Spiders Gnats Moths	Granular	5 oz.	24 hours	Killed	Silver jug tarnished—no other injury.
7/25	New Jersey (L. L. Lehritter)	Cockroach	Granular	1 lb.	24 hours	Nearly all killed	No injury reported.
8/7/24	Florida (F. E. Todd)	Bedbug	"A" Dust	2 lbs.	2 hours	Adults all killed	No injury to furnishings.
7/25/25	Minnesota	Buffalo Moths	Granular	1 lb.	48 hours	Killed	
1/9/26	Cuba (S. W. Bromley)	Furniture-Termites Silverfish Mice Spiders Fleas Book-worm beetle	Granular	1 lb.	92½ hours	100% Killed	
8/25	Pennsylvania (H. N. Worthley)	Bedbug	Granular	1 lb.	36 hours	100% killed	

Experiments with Cyanogas for the fumigation of buildings and for the destruction of fleas in open sheds, etc., are contained in the following article: "The Use of Calcium Cyanide for the Control of Fleas and Other Insects", by K. C. Sullivan, which is reproduced from the Journal of Economic Entomology, Vol. 17, No. 2, April, 1924, p. 230.

Professor Roger C. Smith of the Kansas Agricultural Experiment Station has carried out extensive tests with calcium cyanide to determine its effectiveness and to work out the best methods of application for the fumigation of enclosed spaces. His paper, "House Fumigation with Calcium Cyanide", is reproduced from the Journal of Economic Entomology, Vol. 19, No. 1, February, 1926, p. 65.

The results of various laboratory tests of the toxicity of hydrocyanic acid gas to insects and rodents are reproduced from an article entitled "Calcium Cyanide Fumigation" by S. N. Gore, Indian Journal of Medical Research, Vol. XIII, No. 2, October, 1925, p. 287.

It may be noted that Dr. Gore's conclusion concerning the effectiveness of calcium cyanide used in the open is not in harmony with the results obtained by open air dusting in the control of various insects, reported in Section 6. The method of blowing dust into the rat burrows described in Section 4 has not been used by Dr. Gore. An examination of these sections and Dr. Gore's work clearly indicate that the different conclusions are due to different methods, and in some cases different problems.

THE USE OF CALCIUM CYANIDE FOR THE CONTROL OF FLEAS AND OTHER INSECTS

By K. C. Sullivan, *Columbia, Mo.*

Abstract

Calcium cyanide was successfully used for the control of the Dog fleas (*Ctenocephalus canis* Curtis) and the Human flea (***Pluex irritans*** L) in both open and closed buildings. Calcium cyanide used at the rate of four ounces per 100. sq. ft., will

give practically 100% kill in closed buildings. Eight ounces to 100 sq. ft., in open buildings will give the same results.

Calcium cyanide dust was successfully used for controlling blister beetles (*Epicauta vittata* Fab.), in gardens.

Used at the rate of one ounce to 1500 cu. ft., of space, calcium cyanide dust gave a 95% kill of white fly (*Aleurodes vaporariorum* Westw.) in greenhouses without any injury to plants.

Calcium cyanide dust gave fair results when used at the rate of one ounce to 25 cu. ft., one ounce to 50 cu. ft., and one ounce to 100 cu. ft., for periods varying from 45 minutes to one hour, for the control of San Jose scale (*Aspidiotus perniciosus* Comst.) on nursery stock, apple and peach.

During the past year calcium cyanide has been used at the Missouri Agricultural Experiment Station for the control of a number of different insect pests. Due to the fact that Calcium cyanide is a new product most of the work with it up to the present time has been purely experimental. However, in a number of cases it has been used with very great success in a practical way and on a large scale. The results which have so far been obtained lead us to believe that calcium cyanide has many possibilities and that in the future it can be safely and successfully used for the control of not only certain insect pests but also certain other types of animals such as rodents which destroy annually large quantities of agricultural products. It must be remembered, however, that its use as a remedy for controlling insects is still largely in the experimental stage. In most cases methods of application must be worked out and the dosage necessary to kill particular insects determined. In other words, from the standpoint of an entomologist there are many things which we do not know about calcium cyanide. Therefore, in this paper I shall attempt only to point out some of the possibilities of calcium cyanide when used for the control of fleas and other insects and give a brief resume of the results which have been obtained during only one seasons work. Additional work may, and I believe will, substantiate the results which have been obtained, but on the other hand further experiments should be carried out before definite conclusions are drawn.

Calcium cyanide being a material which gives off hydrocyanic acid gas, one naturally infers that it can be used for fumigating purposes. It may be obtained in three different forms—flakes, granules and dust.

On coming in contact with moisture either from the air or the soil the hydrocyanic acid gas is given off. All of the different forms are easy to handle and where it can be successfully used the process of fumigating is greatly simplified. In some instances it is more desirable to use the

dust form than either the granules or the flakes, as the hydrocyanic acid gas is given off more rapidly from the dust.

During the past summer fleas were very plentiful in Missouri especially through the central portion of the state, with the result that ample opportunity was offered to make some rather extensive tests with calcium cyanide. The credit for the work with fleas is largely due Mr. S W Bromley. This work was carried on in cooperation with the Department of Entomology of the Missouri Agricultural Experiment Station

The first test made was in a modern dwelling house in Columbia, Missouri on July 20, 1923. An Airdale dog was allowed to sleep on the second floor with the result that this floor became badly infested with the dog flea (*Ctenocephalus canis* Curtis). After the infestation was discovered the dog and two cats were kept out doors. The floors were new and of hard wood. The fleas were evidently in the rug, and upon entering this floor numbers of the pest would jump upon the trousers. No fleas were observed in any other part of the house.

The house was fumigated with calcium cyanide flakes at the rate of 4 ozs. to 100 cu. ft. on the second floor where the infestation was present, and one ounce per 100 cu. ft. on the first floor and the basement. The flakes were put down at 8:30 in the morning, the house emptied of its inhabitants and all the windows and doors closed. The flakes were scattered on newspapers on the second and first floor and on the concrete floor in the basement. Flakes were also scattered outside in the new sleeping quarters of the cats and dog, and the animals were treated with kerosene emulsion.

At 5:30 P. M. the house was opened and the newspapers and flakes removed. The flakes were still giving off some gas. A number of dead fleas were shaken from the rug in the badly infested room. During the next few days three or four fleas were found in clothing which were evidently brought in from the outside. No further trouble was experienced and the owner was well satisfied with the results.

Similar results were obtained in the basement of a store in Columbia, Missouri. The owner kept a dog in the basement and it became so badly infested that he feared the fleas would find their way up stairs and attack his customers. The basement was tightly closed and the door fixed so it could be opened from the outside. At 7:30 P. M., July 26, 1923, flakes were scattered on the concrete floor at the rate of two ounces to 100 cu. ft. The place was opened the next morning at

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7:30 and no live fleas could be found. The dog was taken to the country and the owner had no more trouble.

The space under the porch of a dwelling house in Columbia, Mo. became infested with fleas from a dog which bedded there. The owner spent a few minutes under this porch one day examining some pipes and afterwards killed twenty-two fleas on his clothing. The dimensions of the space under the porch was ninety square feet. At 4:15 P. M. August 1, 1923 a little less than two pounds of 50% calcium cyanide dust was uniformly scattered. Three days later no fleas could be noticed under the porch but upon examining a quantity of the debris in the laboratory one live flea was found.

The barns, sheds and hog houses on a farm near Columbia, Mo. became very heavily infested with the human flea (*Pulex irritans* L.) The fleas were so bad that the owner had trouble keeping hired help. Calcium cyanide flakes were scattered by hand at the rate of four ounces to 100 sq. ft. on newspapers which had been spread down in the different buildings. The flakes were put down at 7:30 P. M. July 24, 1923. The newspapers were used so that the residue could be easily cleared away as poultry and hogs had the run of most of the buildings. Wherever possible the buildings were closed but some of the sheds were open on one side. There was no breeze. Conditions were as nearly ideal as possible. The next morning the premises were carefully examined and no living fleas were found except in the tool shed. In this building a few had survived. The application was repeated in this building using eight ounces to 100 cu. ft. Not a single living flea could be found one hour later.

Calcium cyanide used at the rate of eight ounces to 100 sq. ft. can be depended upon to give practically a 100% kill. In a building which can be closed, four ounces to 100 sq. ft. will give the same results.

Some interesting results were also obtained in using calcium cyanide for the control of blister beetles on garden and truck crops. Tests were made with the 50% dust on the striped blister beetle (*Epicauta vittata* Fab.). This blister beetle made a sudden attack on a small garden of about 255 feet square. They were feeding heavily upon beets, and potatoes. A knapsack duster was used and the application was made at about 4:00 P. M. on July 27, 1923. About two pounds of dust was used. Most of the beetles were killed almost instantly. Some, the gas seemed to paralize. First, the rear pair of legs became useless. The beetles would try to pull themselves along with the first two pair when shortly the second pair would cease to function. Then

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in a short time the first pair of legs would become useless. The antennae seemed to be the last organs which were affected. Naturally a few of the beetles escaped before they got enough gas to stop them, also a very small number of the beetles revived enough to crawl away. The garden was examined the following morning. Some of the beetles on the ground were still able to slightly move their legs and antennae. A number of these were collected and brought in the laboratory .Twenty-four hours later they were all dead. Very few of the beetles escaped and the injury they did to the garden was slight. Similar results were obtained in every case where calcium cyanide dust was used for the control of blister beetles.

A few tests were made with calcium cyanide on squash and melon vines for the control of the striped cucumber beetle (*Diabrotica vittata* Fab.), and the squash bug (*Anasa tristis* DeG.). Calcium cyanide flakes used at the rate of one teaspoon per hill killed both the insects and the plants. The granules and the dust gave the same results. Equal parts of calcium cyanide dust and air slacked lime used at the above rate showed no injury to the plants but did not give satisfactory control. However, from the results obtained it seems probable that it will be possible to work out a dosage which can be used satisfactorily for the control of melon pests.

Plant lice succumb quickly to very small quantities of calcium cyanide dust. The dust was successfully used on melons and on Spiraea Van Houtti. It was applied with a small hand bellows. The aphids were almost instantly killed and without injury to the plants.

Recently the Department of Horticulture of the Missouri Agricultural Experiment Station has been depending upon calcium cyanide dust for the control of the white fly (*Aleurodes vaporariorum* Westw.) in their greenhouses. The results have been entirely satisfactory It was first used last May in a greenhouse containing young tomato plants which were badly infested with white fly. The house contained 7758 cu. ft. of space. Eleven ounces of dust was used. It was evenly distributed on the beds thruout the house and some of the dust was placed directly on the leaves. The application was made at 6:10 P. M. May 23, 1923. The house was opened the next morning at 4:35. All adult flies were dead. Most of the larvae and eggs were killed. The pupa appeared to be alive. Seven days later several adults had emerged from the pupa and the few eggs which had not been killed were hatching. Where the calcium cyanide came in contact with the leaves it caused serious

burning, otherwise the plants were not injured. It requires two treatments to thoroughly clean out an infestation of white fly.

A greenhouse containing over fifty different kinds of plants was fumigated December 17, 1923 using one ounce calcium cyanide dust to 1,000 cu. ft. A 95% killl of white fly was obtained and no plants were injured. A temperature of 60 F. was maintained and the house was allowed to fumigate from 7 P. M. to 7 A. M. Calcium cyanide dust used at the rate of one ounce to 2,000 cu. ft., temperature 60° F., gave a 25% kill. The ease and safety with which calcium cyanide can be used seems to indicate that it has possibilities of becoming the standard remedy for the control of white flies in greenhouses. Its effect upon other greenhouse pests has not as yet been studied.

On November 13, 1923 a series of experiments were started to determine the value of calcium cyanide for fumigating nursery stock infested with San Jose Scale (*Aspidiotus perniciosus* Comst.), apple and peach trees were used. The apple trees had two seasons growth from graft, the peach trees were cut backs but with two seasons growth They were grown in an experimental nursery and were badly infested with San Jose Scale. Many of the peach were almost encrusted A tight fumigating box was used Calcium cyanide dust was used at the rate of 1 oz. to 25 cu. ft ; 1 oz. to 50 cu. ft., 1 oz to 100 cu ft ; 1 oz to 200 cu. ft. and 1 oz. to 400 cu. ft. Five sets of trees were used for each strength. The first set was allowed to fumigate for 30 minutes, the second 45 minutes; the third 1 hour; the fourth 1¼ hours and the fifth 2 hours. The trees were dug and placed directly in the fumigating box. The desired quantity of calcium cyanide dust was then spread out on a dry board placed in the center of the box about half way between the bottom and top. After fumigating the trees were reset, and ten days later the first counts were made With every test enough scales were counted to get a fairly accurate average of the percentage of scale killed. The first or the ten day count showed that none of the treatments resulted in a 100% kill. In one case (1 oz. to 200 cu. ft for 30 min.) only 70% of the scales were dead but in most cases the kill was better than 90%. About three weeks after fumigating counts were again made on the first three sets of trees This time 100% of the scale were dead in eight out of fifteen cases. Then again about five weeks after fumigating the third counts were made on all of the twenty-five different tests. Live scales were found only on nine. The following table shows a complete record of all counts made and the results obtained

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The Use of Calcium Cyanide for the Fumigation of Peach and Apple Trees for San Jose Scale

Amount of material used	Date of treatment	Date counted	Kind of tree	Percent scale dead for different periods of treatment: 30 Min.	45 Min.	1 Hr.	1½ Hrs.	2 Hrs.
1 oz. to 25 cu. ft.	11/13/23	11/23/23	Peach	90.5	94.5	96.4	99.3	83.5
	11/13/23	11/30/23	Peach	96.5	99.0	96.5	99.0	94.5
			Apple		100.0			
	11/13/23	12/21/23	Peach	100.0	100.0	100.0	98.5	100.0
			apple		100.0	100.0		
1 oz. to 50 cu. ft.	11/16/23	12/26/23	Peach	83.3	90.0	94.0	96.8	96.8
			Apple		100.0			
	11/16/23	12/6/23	Peach	91.0	100.0	100.0	96.8	98.5
			Apple	99.2				
	11/16/23	12/20/23	Peach	100.0	100.0	99.5	100.0	100.0
			Apple	100.0	100.0	100.0	100.0	100.0
1 oz. to 100 cu. ft.	11/17/23	11/28/23	Peach	98.6	95.0	90.5	91.7	96.5
			Apple		96.0		92.3	
	11/17/23	12/7/23	Peach		100.0		100.0	94.5
			Apple	100.0	99.0	98.6	100.0	
		12/20/23	Peach		100.0	98.6	100.0	100.0
			Apple	100.0	100.0	96.8	100.0	100.0
1 oz. to 200 cu. ft.	11/20/23	11/30/23	Peach	70.0	87.0	93.9	70.0	95.0
			Apple	97.0		93.5		96.0
	11/20/23	12/20/23	Peach	93.5	97.5	99.0	100.0	100.0
			Apple	98.0	100.0		100.0	
1 oz. to 400 cu. ft.	11/24/23	12/6/23	Peach	97.0	50.0	97.7	100.0	95.5
			Apple			86.2	99.0	100.0
	11/24/23	12/20/23	Peach	82.0	68.1	93.7	100.0	100.0
			Apple	54.7		100.0	100.0	100.0
Check.		12/28/23	Peach Percent Scale dead 62.9					
			Apple Percent Scale dead 53.3					

From the results one would naturally draw the conclusion that calcium cyanide kills slowly. However, on the first counts made wherever it was doubtful whether a scale was alive or dead it was considered as a live individual. At the time when the last counts were made there was no question about the live or dead individuals. They were easy to distinguish. This probably explains the difference in the percent of kill between the first and last counts. Also the results seem to indicate that calcium cyanide used at the rate of 1 oz. to 100 cu. ft. will give just as good results as when used at the rate of 1 oz. to 25 cu. ft. The thirty minute treatments gave just as good results as the two

hour treatments at the above strength. With the weaker concentrations the period of fumigation must be lengthened as one ounce of calcium cyanide to 200 cu. ft. and to 400 cu. ft., gave 100% kill only for the 1½ and the 2 hour periods.

The writer has done considerable work with both potassium cyanide and sodium cyanide in the control of scale insects on nursery stock and the results so far obtained with calcium cyanide are practically as good as those which have been obtained with the other materials. However, the writer is not ready to fully recommend calcium cyanide for fumigating nursery stock until additional data have been obtained as to its effect both on the scale and on the plants.

It is hoped that others will pursue the work with calcium cyanide It undoubtedly offers great possibilities and if additional experiments show that it can be successfully used for fumigating nursery stock the process will be greatly simplified.

HOUSE FUMIGATION WITH CALCIUM CYANIDE[1]

By Roger C. Smith, *Kansas Agricultural Experiment Station*

Abstract

This paper embodies the results of 18 fumigations with calcium cyanide for household insects, covering a period of two years. After six more or less preliminary tests with different forms of the cyanide, various dosages, and methods of application, it was decided that two pounds of calcium cyanide granules, or "G grade" to 1000 cubic feet of space applied by spreading thinly on dry papers in tightly closed rooms, and left for twenty-four hours, should give satisfactory results. Temperatures and humidities were recorded. Usually some insects in vials closed with one thickness of cheese cloth were used as checks. In only two fumigations out of the 18 were the results unsatisfactory, and one of these is not regarded as being significant because of special conditions involved. Tarnishing of metals, discoloration of walls and

[1]Contribution No. 352 from the Entomological Laboratory, Kansas State Agricultural College. Acknowledgment is made to the American Cyanamid Company for the cyanide used in about a third of the trials and for suggestions; to Mr. H. L. Gui, Prof. J. W. McColloch, Mr. C. B. Keck and Mr. Elmer Jones for their assistance with the fumigations, and to Prof. W. L. Latshaw for suggestions regarding the chemical aspects of this work.

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spotting of bath room equipment occurred in four fumigations in various degrees. In three cases it was probably due to an unfavorable secondary reaction resulting from an excess of moisture used; in the fourth it might have been due to the high humidity prevailing. An exact knowledge of the chemical reaction with water of the product is needed. It costs about one-third less to fumigate with calcium cyanide than with sodium cyanide; it is a simpler process, and less dangerous to the one doing the work. The odor in the houses lasting for from one to five days or more is objectionable. It is concluded that calcium cyanide is a promising substitute for sodium cyanide for house fumigation.

Calcium cyanide first became available at Manhattan, during the Spring of 1923. It was promptly planned to give it a trial in house fumigation. This paper is a summary of these tests to date.

Sullivan (1924) has reported upon some house fumigations with this material for two species of fleas. He stated that "Calcium cyanide used at the rate of four ounces per 100 square feet will give practically 100 per cent kill in closed buildings." He also stated that eight ounces to 100 square feet would give the same result in open buildings. In one experiment he obtained apparently satisfactory results with one ounce of calcium cyanide flakes to 100 cubic feet of space on a first floor and basement of a modern dwelling. Two ounces of flakes to 100 cubic feet of space in a basement gave similar results in another test.

The American Cyanamid Company, in its leaflets and through its agents, has recommended one pound of "A" dust to 1000 cubic feet for eight hours, as stated by Hungerford (1925).

The method used in the tests reported in this paper, with the exception of the first two trials, is largely that used by Sullivan, but embodying in addition suggestions of Dr. Moore, given orally and in correspondence. The method was varied somewhat in the tests as indicated. In all cases, the buildings were prepared as for hydrocyanic acid gas fumigation, generated from sodium cyanide. Table I gives a summary of all the tests made in the period 1923 to November 1, 1925.

Discussion of Individual Trials. The first experiment will be discussed rather fully because of the method followed and the interesting results obtained. The building, which was a comparatively new, well-built bungalow, had the basement severely infested with dog fleas. Since they had been carried to the rooms above, it was thought that a complete fumigation was necessary. Calcium cyanide was then new and, to the writer's knowledge, no experiments with it in house fumigation had been made. It was reasoned that sufficient moisture should be applied to set free the gas quickly so as to surround the insects with a lethal dose in the first few minutes, as occurs in sodium cyanide fumigation. Moore (1924) states that the concentration of the gas to which

the insects are exposed is of more importance than the length of exposure. Since the gas evolves relatively slowly when the flakes are scattered on the floor or ground, it was decided to place the cyanide in pasteboard boxes, buckets or pans and then pour a small amount of water equal to about half the volume of the flakes over them. All of these containers were tried. Precautions were taken to prevent damage to the floors.

The insects in the check cages consisting of May beetles, ground beetles, and alfalfa insects, because they happened to be easily obtained, were all dead in three hours. The house was opened after twenty hours and no live fleas were found then or later. Severe tarnishing, however, resulted. The leather cover of a thermos bottle in the dining room appeared as if it were covered with frost or mildew. The silver candle sticks, electric fan, chandeliers, and silverware were severely tarnished by a brownish or smoky deposit. The white enameled wood work in the bath room and kitchen, the white wainscoting, the bath tub and stool had large brownish or reddish blotches on them, apparently where water had at some time previously been splashed on them, or where they had been wiped with a damp rag. It appeared as if dirty water had been splashed on the woodwork and dried. It was thought that soap in the water is in some way responsible for the blotches, for clean water leaves no residue when it evaporates. The walls of the bath room, which were painted blue, had a very distinct reddish or pinkish tinge after the fumigation, and the walls in the two front rooms, which were painted brown, had a marked reddish tinge.

Soon after the start of the fumigation, the cyanide in the bucket in the dining room foamed up and ran over. The door was opened slightly and an effort was made to drag the bucket out with a long pole. But as soon as the door was opened, the gas fumes came out so strongly that a severe smarting of the eyes was experienced.

Moore (1924) states that "if sufficient water is used to wet the material, another reaction occurs in which the hydrocyanic acid decomposes under alkaline conditions, with the formation of ammonia and other little known compounds, one of which is often referred to as azulmic acid." This ammonia, then, in Dr. Moore's judgment, caused the smarting of the eyes and the discoloration, instead of some impurity in the flakes, as the writer suggested. He stated further (1924) that "if the flakes are placed in buckets or jars and water poured over them, a solution of calcium cyanide will be formed which does not give off hydrocyanic acid any more rapidly than a similar solution of sodium cyanide."

TABLE I—FUMIGATION TESTS WITH CALCIUM CYANIDE FOR ERADICATION OF HOUSEHOLD PESTS

House number	Date	Insect	Check	Temperature[1]	Humidity[1]	Form of cyanide	Rate per 1000 cu. ft.	Type of building	Total amount used	How applied	Length of time exposed	Results	Check	Remarks
No. 1	7-12-23	Fleas	Alfalfa sweepings in screen cages	83°F.	85	Flakes	3 lbs. to 1600 cu. ft.	New bungalow	25 lbs. to 9991 cu. ft.	Various	20 hrs.	Satisfactory	All killed in 3 hrs.	Tarnished leather and silver, spotted woodwork, discolored the walls
No. 2	7-18-23	Fleas	None	87°F.	80	Flakes	2 lbs. to 1600 cu ft.	Basement	8 lbs. to 6400 cu. ft.	Pasteboard boxes. Poured water on it	28 hrs. 1 week	Partial. Complete in few days		No damage done
No. 3	8-10-23	Bed bugs	None	96°F.	74	Flakes	3 lbs. to 1600 cu. ft.	Old two-story residence		Spread on dampened paper	24 hrs.	Satisfactory		No damage done
No. 4	4-11-24	Bed bugs	Ground beetles, etc.	81-75°F.	43-53	Granules	3 lbs. to 1600 cu. ft.	Bungalow	9½ lbs. to 4621 cu. ft.	As above	24 hrs.	Satisfactory	All dead	Slight tarnish on typewriter and alarm clock
No. 5	6-7-24	Bed bugs	Chrysomelids & alfalfa sweepings	70-80°F.	82-86	Flakes	2 lbs. to 1000 cu. ft.	Old two-story residence	19 lbs. to 7800 cu. ft.	As above	8½ hours	Satisfactory	All killed. 1 ladybird beetle revived in open	No damage done.
No. 6	6-11-24	Bed bugs	Silkworms Alfalfa sweepings	73-83°F.	100-82	Granules	1½ lbs. to 1600 cu. ft.	Old two-story residence	8 lbs. to 7369 cu. ft.	As above	22½ hrs.	Satisfactory	All dead	Woodwork discolored. Silverware & sewingm'ch'ne tarnished
No. 7	10-13-24	Ants	None	68°F.	88	Flakes	Indefinate	New bungalow	Indefinate	In between walls; under soil in basement	9 hrs.	Satisfactory		No damage done
No. 8	7-20-25	German cockroach	Cockroaches	79°F.	85	Granules	2 lbs.	Modern two-story residence	25 lbs. to 12,336 cu. ft.	Spread on dry papers	11 hrs.	Satisfactory	All dead	No tarnishing observed
No. 9	7-25-25	Fleas	Fleas	82°F.	87	G Grade	2 lbs.	Two-story residence	50 lbs. to 25,757 cu. ft.	Spread on papers	24 hrs.	Satisfactory	All dead	No tarnishing or spotting noted

No. 10	7-22-25	Fleas	Fleas	71°F.	76	Granules	2 lbs.	Two-story residence	42 lbs. to 19,364 cu. ft.	Spread on dry papers except on porch	21 hrs.	Satisfactory	All dead	No tarnishing or discoloring observed
No. 11	7-26-25	Angoumois grain moths Clothes moths	None	80°F.	85	G Grade	2 lbs.	Modern bungalow	20 lbs. to 10,420 cu. ft.	Spread on dry news papers	20 hrs.	Only partial kill		Silverware tarnished. Brownish deposits on woodwork & bath tub
No. 12	8-1-25	Indian meal moths	None	73°F.	65	G Grade	1 lb.	New grain barn. Two floors	50 lbs. to about 50,000 cu. ft.	Spread on dry papers	38 hrs.	Successful		No damage observed or reported
No. 13	8-29-25	Cockroaches	None	84°F.	60	G Grade	3 lbs.	Old remodeled store room	50 lbs. to 15,364 cu. ft.	Spread on dry papers	23 hours	Unsuccessful		No damage observed or reported
No. 14	9-1-25	Fleas	None	83°F.	60	G Grade	2 lbs.	Two-story residence	45 lbs. to 22,154 cu. ft.	Spread on dry papers	25 hrs.	Satisfactory		No damage observed
No. 15	9-7-25	Fleas	None	83°F.	72	G Grade	2 lbs.	New garage	3 lbs to 1440 cu. ft.	Spread on dry papers	24 hrs.	Satisfactory		
No. 16	9-9-25	Fleas	None	79°F.	87	G Grade	2 lbs.	Residence 2 floors	30 lbs.	Spread on dry papers	18 hrs.	Satisfactory		No damage done
No. 17	6-25-25	Fleas	Fleas 5 vials	76°F.	90	Flakes	1 to 2 pounds	Residence 2 floors and basement	22 lbs. to 15,072 cu. ft.	Spread on dry or dampened papers	17½ hrs.	Satisfactory	All inside dead. All on porches alive	No damage done. Flakes not exhausted
No 18	7-3-25	Bed bugs	Bed bugs in vials under bedding	98°F.	86	G Grade	2 lbs.	Residence 2 floors	5 lbs. to 2780 cu. ft.	Spread on dry news papers	25 hrs.	Satisfactory	All dead	No damage seen nor reported

[1]Temperature and humidity computations in houses 1 to 7 were obtained from a hygrothermograph in the buildings; in 18, from wet and dry bulb thermometers and for the rest, averages of readings at the college for the period of the fumigation are given. All of these records are regarded only as approximate.

It is well known that hydrocyanic acid gas is dissolved readily by water, forming prussic acid.

Fortunately, all the deposits or discolorations wiped off easily, and after several weeks, the reddish tinge of the painted walls disappeared without any treatment. There was, however, as a result of the fumigation, a distinct odor in the house for several weeks, but the occupants apparently did not object to it, and it gradually disappeared.

In house No. 2, only the basement was infested with dog fleas. Half of the basement was cemented and half was dirt floor. The eight pounds of calcium cyanide flakes were divided into three lots and placed in pasteboard boxes lined with paper and about a pint of water poured over each of them. Salt was sprinkled on the floor of the basement to drive the fleas up off the floor. The odor of gas was strong, and was detected as much as 100 feet on three sides by neighbors. After 28 hours, an examination revealed some live fleas, but in greatly reduced numbers. The owner then decided to close up the basement and leave it to fumigate longer. The writer objected strongly to this, since the owner was planning to occupy an upstairs room. Nevertheless, he did it without injury to himself, and in a week reported the fleas all gone. No injuries to anything were observed or reported.

About the time house No. 3 was fumigated, the writer was informed by Dr. Moore of the method used in Missouri, viz., of scattering the cyanide on lightly dampened newspapers. This house, which was a very poorly built shack of three rooms, crowded with old furniture and clothing, was fumigated according to this method. After 24 hours, nothing alive was found and no damage was done. The idea of bringing about a rapid evolution of gas was abandoned and greater reliance placed on longer exposure, a principle found to be effective by Saffro (1924).

House No. 4 was much like No. 3; that is, poorly built and much crowded. The granular form of the cyanide was used here for the first time and was spread on papers as before. The fumigation was a complete success. The linoleum in the kitchen was stained slightly under the cyanide, the discoloration suggesting scorching. Since the owner did not have sufficient newspapers to spread on the floor, the spot was not a surprise. It has since been found that a half dozen thicknesses of newspaper over linoleum are none too many. Slight tarnishing afterwards was observed on the typewriter and an alarm clock, but they were so slight that the owner did not even see them. The fumigation was entirely successful.

House No. 5 was a very large old rooming house, poorly built and full of old furniture. The occupants could not leave for more than eight hours, so the time of exposure was shorter than in previous fumigations. The cyanide was placed on slightly dampened papers.

The fumigation was apparently successful, since no reports of further infestation were ever made. No tarnishing was observed or reported. Since one beetle in a check cage revived, it was thought that the results were not successful. But since the owner, who is the janitor of a college building and is seen daily, never reported finding bugs subsequently, the results were apparently satisfactory.

House No. 6 was a well-built, remodeled old house only occupied about two weeks by a newly married couple. Granules were used in this fumigation. They were scattered very thinly and uniformly on slightly dampened papers. Particular precaution was taken with checks. As in the previous fumigations, whatever insects could be had quickly or conveniently were used. In this case, the insects obtained from alfalfa sweepings and about a dozen boxes containing silk worms were used. They were placed in different places in the house; in the bed, under covers, under carpets, in a trunk, in a bureau drawer, above the door, and in a closet. As a result of this fumigation, all the check insects were dead. It appeared that they had been killed quickly and suddenly. Some appeared to have been killed while eating. No further infestation was ever reported. There was some discoloration in the building, but it was not serious, and very likely if attention had not been called to it, it would not have been observed by the occupants. The discoloration pertained to the white, newly painted, woodwork similar to that of house No. 1. It was less extensive and came off with Sunbright cleaner. The silverware, alarm clock, the nickelplating on the sewing machine, and some cooking utensils were slightly darkened or tarnished. In an attic above the kitchen which was also fumigated, the owner put too much water on the paper and as a result caused a brown spot about a foot square in the ceiling below. These discolorations, except the ceiling spot, were not serious and the fumigation was considered as a complete success.

House No. 7 was a poorly built but not very old bungalow. Ants of the species *Lasius (Acanthomops) interjectus*[2] had entered the basement through cracks in the cement floor and had carried in several bushels of soil. This soil was scooped from over the cracks, about a pint of the granules scattered over them and then covered with the soil.

[2]These ants were determined by M. R. Smith.

The ants were apparently destroyed, since no activity was observed or reported later. No discoloration or similar damage was done.

In houses No. 17 and 18, particular attention was given to the checks. In both cases, vials of the offending insects, closed with one thickness of cheese-cloth, were placed in different rooms, in beds, or variously secreted. Other vials were left outside of the house to see if any insects died because of the confinement. In No. 17, the amount of materials and method of application was varied. One pound of calcium cyanide flakes to 1000 cubic feet, spread on dampened papers, was used on the first floor; two pounds to 1000 cubic feet, spread on dry papers, was used upstairs and in the basement. In both houses, the insects in the vials in the rooms were all dead at the end of the fumigation, while those in the vials outside were all alive. Both fumigations were entirely successful and no discolorations were seen or reported.

Tests numbers 8 to 16 inclusive can be discussed together, for the same method was followed in all. From the earlier fumigations, and because of the cyanide content of the product, it was decided that in the usual house fumigation, two pounds of calcium cyanide to a thousand cubic feet of space and left for 24 hours should be ample. The granular form, or G grade, was selected for further tests, because the smaller particles, theoretically at least, should give off the gas more rapidly than the flakes. The "A" dust was not yet available at Manhattan, and the granular form was the finest grade obtainable, except the dust mixtures. It was decided to spread them thinly on dry newspapers, unless the humidity was exceptionally low. Then a very light sprinkling of the papers before spreading the granules would be resorted to, which was done only on the porch of No. 10.

In the second series, only numbers 11 and 13 were unsatisfactory. The owner said that house No. 11 was infested with clothes moths, but it was learned several months after the fumigation that the moths seen were Angoumois grain moths. They were breeding in a jar of old pop-corn which had been forgotten. Probably there were some clothes moths present at or before the fumigation, for injuries were seen, but if they were there at the time of the fumigation, all succumbed, for no new injuries were observed afterwards. Some dead angoumois grain moths were found after the fumigation, but the owner reported seeing many live ones about three weeks later. The fumigation was done on a hot, sultry day. There is indicated here, as well as in other fumigations, that there may at times be sufficient moisture in the air to cause tarnish-

ing and spotting, for no moisture was used on the papers in this fumigation.

This house was again fumigated in the same manner, Jan. 15, 1926. This was a warm, winter day, and a good fire had previously been made in the furnace to raise the temperature to 70° or higher. The humidity was about 45 per cent. The fumigation was continued for 27 hours. Only a small per cent of the Angoumois adults were killed. No tarnishing or spotting of any kind was observed as a result of the fumigation. Adults emerged from the popcorn after the fumigation, so it appears that this material is unsuccessful for Angoumois grain moths. It is known, however, that this moth is very resistant to HC_n, though this method of exterminating them is usually given in bulletins.

The blotches on the white woodwork and bath tub following the earlier fumigation again strongly suggested a connection with soapy water.

The American Cyanamid Company states that calcium cyanide granules contain not less than 40 per cent nor more than 50 per cent calcium cyanide. It seems highly probable that the remaining 50 or 60 per cent of the product consists largely of unconverted $CaCn_2$, or calcium cyanamid and some calcium hydroxide. The following reactions are given in the American Cyanamid Company's leaflets (1, p. G 1).

(a) $CaCn_2+3\ H_2O=Ca\ (O\ H)_2+CO\ (N\ H_2)_2$

(b) $Ca\ (CN)_2+2\ H_2O=Ca\ (O\ H)_2+2\ H\ Cn.$

"When calcium cyanide is acted upon, by moisture, urea is formed, whereas when calcium cyanide is acted upon by atmospheric water vapor, hydrocyanic acid is given off." The ammonium compound $CO\ (N\ H_2)_2$ of (a) is a weak base which might be dissociated by $Ca\ (O\ H)_2$, a strong base, with dry ammonia gas resulting. This might react with certain paint pigments and dyes and might explain the discolorations obtained in fumigation No. 1, and in some others where there was a high humidity. It is evident by comparing the above reactions that more water is required for (a) than for (b).

The odor which follows fumigations with calcium cyanide is perhaps explainable for the reason that certain materials about rooms might absorb the ammonia gas and perhaps other gases evolved until a high concentration is reached. Upon airing out the house, these absorbed products would be given off until equilibrium, or, in this case, normal conditions are attained. But the final explanation depends on an exact knowledge of the chemical composition of calcium cyanide and its chemical behavior under fumigating conditions.

A part of the tea room, No. 13, was refumigated when it was found

that there were still present live cockroaches after the first fumigation. Only the kitchen and store-room (7752 cu. ft.) were refumigated. A very heavy charge of 25 pounds was used. As before, a great many dead roaches were found, but apparently many were not reached, since live ones were seen several days later. A reinfestation after the first fumigation from buildings, including a restaurant near by, is a possibility. There was no basement under the building, and the live cockroaches, after the fumigations, may have come from under the building. We are not inclined to regard this trial as a significant failure, for there was a very heavy kill of roaches at each fumigation, and also one rat in each case. It was a special condition which possibly was not fully met. The tea room had been fumigated a year previous with sodium cyanide, so that the reinfestation strongly indicates migrations from near-by buildings. One or more dead mice were found after perhaps a third of these fumigations. They were usually in plain view in the rooms and not in their usual hiding places.

General Summary and Conclusions. There are only two unsatisfactory trials in the eighteen, one of these, No. 13, not being regarded as significant. Therefore, calcium cyanide may be said to be a promising substitute for sodium cyanide for house fumigation. Two pounds to 1000 cubic feet of space in the average, fairly well-built residence, in general, proved satisfactory. The minimum dose is, of course, somewhat less than this amount, but it is thought that it is advisable to use an excess to meet the variety of conditions under which it would be certain to be used. The twenty-four hour period for the fumigation is longer also than necessary, at least in most cases, but the longer period was used to insure satisfactory results. All the tarnishing and spotting, except in No. 11, may have been due to the use of moisture, and thus in later fumigations no water was used and a longer period of exposure was urged upon the tenants. There is no clear evidence that changes in temperature and humidity occurring during these fumigations influenced the results. There is a suggestion that spotting may be more severe at high humidities than at low ones.

The advantages of the substitution of calcium cyanide for sodium cyanide in house fumigation are:

1. It is easy to use. The handling of the sulphuric acid, which is the most disagreeable part of sodium cyanide fumigation, is eliminated. This method requires few instructions and little or no skill to carry it out. Injury by the acid to floors, carpets and clothing is eliminated.

2. The danger in using the gas is reduced. The gas evolves more

slowly than with sodium cyanide, allowing the operator plenty of time to get out from difficult places. The odor of the gas or gases involved might serve as a warning to persons about to enter a house in the process of fumigation.

3. It is cheaper to fumigate a house with calcium cyanide at the rate of two pounds to 1000 cubic feet than with sodium cyanide at the rate of one pound to 1600 cubic feet. It requires no equipment other than a good supply of newspapers, or wrapping papers, a paper sack for each room, and a scales for weighing the cyanide.

The retail prices per pound at Manhattan for calcium cyanide flakes and for the G grade, or granules, in five-pound cans is forty-five cents; in 25-pound cans it is thirty cents.[3] Sodium cyanide sells for seventy-five cents a pound in a one-pound package, and sixty cents a pound in five-pound containers. Commercial sulphuric acid is thirty cents per pint, or fifty cents a quart, where containers are furnished. Calculating labor at fifty cents an hour and using calcium cyanide at two pounds to 1000 cu. ft., and sodium cyanide at one pound, one and one-half pints sulphuric acid to 1600 cu. ft. (or 1000 cu. ft. in basements), a comparison of costs in fumigating several of the houses listed with the two formulae is shown in Table II. The labor cost in the calcium cyanide fumigations is in all cases the exact amount paid for these fumigations. The labor cost in the sodium cyanide fumigations is an estimate based on an average of fifteen minutes of time necessary to accomplish all the operations for each room fumigated.

TABLE II. COMPARATIVE COSTS OF FUMIGATING CERTAIN HOUSES WITH CALCIUM CYANIDE AND WITH SODIUM CYANIDE

	Actual cost of fumigating with calcium cyanide			Estimated cost of fumigating with sodium cyanide				
House number	Labor	Materials	Total	Labor	Cyanide	Acid	Crock rentals 15c each	Total
8	$1.50	$7.50	$9.00	$1.25	$6.00	$3.38	$1.65	$12.28
9	2.00	15.00	17.00	2.25	10.80	8.07	1.95	23.07
11	1.00	4.50	5.50	1.00	3.60	2.25	.90	7.75
16	2.00	9.00	11.00	1.25	8.40	5.25	1.50	16.40

The difference in cost is chiefly due to the saving in eliminating the acid, which involves, in addition to its own cost in nearly every house fumigation, a rental of crocks to contain the mixture. The local rate for rental is twenty per cent of the value of the crocks. In addition to this charge, about one in every twelve crocks used will be broken and will have to be paid for by the one renting the crocks. Breakage was not included in these estimates.

[3]The retail price quoted by the company is thirty-four cents a pound in 25-pound cans, and in 5-pound cans it is fifty cents a pound.

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The following objectionable features were observed:

1. Discolorations and tarnishing of leather goods, nickel and silver-plated objects and of white woodwork may occur. In houses Nos. 6 and 11, no satisfactory explanation of this can be made. These discolorations, while not serious, are objectionable. We need to know more about the chemical composition of calcium cyanide and its reactions before a final explanation can be given.

2. There is a discernible odor in the house for a day to as much as a week or more. No one has reported this as seriously objectionable, but it will likely prove to be objectionable to some. Airing out the house does not eliminate the odor. It disappears gradually with or without airing. Since this odor does not follow sodium cyanide fumigation, there must be some impurity, or chemical reaction responsible for it. Perhaps the odor will be explained when the tarnishing and spotting is understood.

Suggested Precautions in Using Calcium Cyanide for House Fumigations

1. It should be weighed out doors to lessen the danger from the gas. One should work rapidly, for gas is given off then, as indicated by the slight change in color.

2. The material should be scattered very thinly on the papers. If piled up, the covered portion does not give off all or any of its gas.

3. There was some indication that granules are better than flakes for house fumigation, that small particles give up a larger percentage of their gas in a given length of time than larger ones. When the flakes were removed at the end of the fumigating from houses numbers 5 and 17, some of the flakes appeared wholly unchanged.

4. Place plenty of newspapers on the floor. The cyanide may stain the floor and especially linoleum through one or two thicknesses of paper.

5. Until its action and use are better understood, the dampening of the papers before sprinkling the cyanide on them should be omitted. It appears to be unnecessary generally, and causes an increase in discoloring.

6. Especial attention should be given to airing out rooms before entering. Sometimes the gas persists in closets and basements. An electric fan was found useful to facilitate this part of the work.

Literature Cited

1. American Cyanamid Company. Leaflets entitled "Research in the Development of Calcium Cyanide." Distributed November, 1925.

2. HUNGERFORD, H. B. Insect Pests about the House. *In* the twenty-fourth Biennial Report, Kansas Board of Agriculture, 1924, pp. 83–120. (Reference on p. 116–117).
3. MOORE, WILLIAM. Calcium cyanide. Jour. Econ. Ent., 1924. 17:104–106.
4. SAFFRO, V. I. Calcium Cyanide as a Greenhouse Fumigant. Jour. Econ. Ent., 1924, 17:667.
5. SULLIVAN, K. C. The use of Calcium Cyanide for the Control of Fleas and other Insects. Jour. Econ. Ent., 1924, 17:230–237.

CALCIUM CYANIDE FUMIGATION.

BY

S. N. GORÉ, L.M. & S.
(*Bombay Bacteriological Laboratory*).

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IN fumigation operations carried out with hydrocyanic acid gas, this gas has been produced by the action of strong sulphuric acid on either potassium or sodium cyanide.

A method of generating hydrocyanic acid gas is by means of calcium cyanide, which has the property of evolving the gas on mere exposure to air and the water vapour normally contained in it. The use of corrosive liquid and the inconvenience of generating the gas are obviated; further the residue left after the calcium cyanide has been fully exposed is said to be ordinary slaked lime.

The calcium cyanide used was in fine powder form and smelt strongly of hydrocyanic acid.

As a result of experimental work carried out since 1915 at the Bombay Bacteriological Laboratory in connection with hydrocyanic acid gas fumigation, it had been ascertained that the lethal effect of this gas depends upon two factors, viz., the concentration of gas and the period of exposure. It was found that a concentration of 50 parts of hydrocyanic acid gas per 100,000 of air and half an hour's exposure sufficed to kill rats, fleas and bugs. It is interesting to note that mosquitoes are very susceptible to this gas and a concentration of about 6 parts per 100,000 and a period of exposure of a few minutes kills them.

The following are the details of the experiments carried out with the calcium cyanide.

EXPERIMENT I.

This experiment was instituted to determine the comparative concentration of HCN immediately over the surface of unused and used calcium cyanide and of sodium cyanide.

For this purpose one ounce of each of the respective materials was placed in a six-ounce wide-mouth bottle and five litres of air drawn past a point just above the surface of the material. The air was passed through a solution of caustic

soda which retained the hydrocyanic acid gas in the form of sodium cyanide. The solution was titrated with a standard silver nitrate solution and the concentration of hydrocyanic acid gas determined. The results obtained are shown in the following table: —

TABLE I.

Material.	Parts of HCN per 100,000 of air.
Unused calcium cyanide	340
Used calcium cyanide	4
Sodium cyanide	4

This experiment shows that when calcium cyanide is exposed to air, HCN is rapidly given off and that after exposure very little gas is given off.

EXPERIMENT II.

This experiment was performed to determine the effect of calcium cyanide when sprinkled on surfaces containing insects—the insect selected in this experiment being the bug.

Twenty bugs were placed in a tray and some calcium cyanide was sprinkled on them. The immediate effect was that a few bugs ceased to move while others moved away towards the sides of the tray. However, after an hour all bugs except three were found to be lively, while the three motionless bugs were found to be still alive after four hours. These twenty bugs were selected ones, i.e., out of a number of bugs, those that were quite active were taken for this experiment.

A similar experiment was done with a mass of bugs. In this mass several bugs were observed moving. This mass was put in a tray and some calcium cyanide sprinkled on them. Except a few bugs, which did not revive even on the next day, all moved away towards the sides of the tray.

EXPERIMENT III.

To determine the effect of sprinkling calcium cyanide in an eight ounce beaker covered with fine copper wire gauze and containing fleas.

About 20 fleas were used in this experiment and about half a gramme of calcium cyanide used. At the end of six hours most of tne fleas were found to be active.

EXPERIMENT IV.

In a pit 90 inches in diameter and 42 inches deep containing rat fleas, two guinea-pigs were allowed to run about for about 15 minutes. The guinea-pigs were taken out of the pit and about 200 fleas were picked off their fur. These fleas were put back in the pit and 2 ounces of calcium cyanide was sprinkled in the pit, which was then closed up with a wooden cover.

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The next morning the cover was removed, and two guinea-pigs allowed to run about in the pit for half an hour. On taking a count of the fleas it was found that one guinea-pig showed 11 fleas while the other 16 fleas alive.

In another similar experiment 68 fleas were put in and next morning 40 fleas were removed alive.

Experiments 2 to 4 go to show that the sprinkling process is not effective in killing bugs and fleas.

Experiment V.

As it is likely that sufficient concentration for a sufficient period was not obtained in experiments 2 to 4, this experiment was conducted in the fumigation chamber. This is a glass case with a capacity of 200 c. ft. It is fitted up so as to render it possible to take the concentration of the gas inside the chamber and to introduce and remove experimental rodents and insects, while the chamber is charged with hydrocyanic acid gas.

One ounce of the calcium cyanide was thinly spread on a sheet of paper placed in the middle of the floor of this chamber. Two points were selected for drawing samples of the chamber air. Point *A* was just above the calcium cyanide and point *B* was three feet away and above the powder. Rats and fleas were put in a small compartment in connection with chamber air. This compartment was close to point *B*. The details of this experiment are given in Table II.

Table II.

One ounce of calcium cyanide was introduced into the chamber at 10 a.m.

Time at which test was started.	Period approximate in hours since the dust was put in the chamber.	Parts of HCN per 100,000 parts of the air in the chamber at point *B*.	Remarks.
11- 0 a.m.	1 hr.	26	....
11-37 a.m	1½ hr	37	Rat introduced; it succumbed in 18 minutes.
1-33 p.m.	3½ hrs.	36	Rat introduced; it died after 39 minutes exposure.
2-33 p.m.	4½ hrs.	34	....
3-40 p.m.	5½ hrs.	32	....
3-45 p.m.	...	...	Rat introduced; it ceased breathing after 20 minutes exposure.
..	24 hrs.	17	..
..	25 hrs.	20	..
.	27 hrs.	11	.
..	48 hrs.	4	..

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From this experiment it will be seen that

(1) half ounce of calcium cyanide per 100 c. ft. of a fairly air-tight space gave a concentration of about 35 parts per 100,000, which lasted for about four hours. This concentration was attained in about two hours time after introducing the dust into the chamber;

(2) rats exposed to a concentration varying from 37 to 32 died within an hour; and

(3) in 24 hours the concentration fell by one-third

Experiment VI.

This experiment was similar to Experiment V. Instead of 1 ounce, 2 ounces of calcium cyanide were used The results are given in Table III. Experiment started 10-25 a.m.

Table III.

Time at which test was started.	Period	Parts of HCN per 100,000 of air	Remarks.
10-55 a.m.	½ hr	42	Rat died in 7 minutes.
11-25 a.m	1 hr.	56	Rat died in 5 minutes.
12-25 p.m.	2 hrs.	62	Rat gasping in 6 minutes; removed to fresh air, but did not revive.
1-25 p.m.	3 hrs.	59	Fleas exposed in a test tube covered with copper wire gauze. All fleas motionless in 5 minutes. Removed into fresh air after 18 minutes exposure. None of these fleas revived.
2-25 p.m.	4 hrs.	55	Fleas exposed for 15 minutes. Did not revive on removal.
3-25 p.m.	5 hrs.	43	....
4-25 p.m.	6 hrs.	35	....
....	23 hrs.	25	....
....	27 hrs.	18	....

This experiment shows that when the concentration was somewhere near ~~50 parts per 100,000, a few minutes~~ exposure sufficed to kill rats and fleas.

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Experiment VII

This experiment was similar to the previous one except that one ounce of calcium cyanide was used and that estimations were taken from points *A* and *B* referred to in Experiment V. Results of the experiment are given in Table IV.

Table IV

One ounce of calcium cyanide was introduced into the chamber at 11 a.m.

Time at which test was started.	Period.	Parts of HCN per 100,000 at point *A*	*B*	Remarks
11-10 a.m.	10 mins	290		
11-27 a.m.	27 mins	.	5	
11-35 a.m.	35 mins	160	.	
11-45 a.m.	45 mins	225	..	
12-0 noon	1 hr	.	15	
12-20 p.m.	1 hr 20 mins	.	..	Rat introduced; ceased breathing in 1½ hr
1-10 p.m.	2 hrs.		45	...
2-13 p.m.	3 hrs.		51	....
2-22 p.m.	...	52	.	Fleas put in, in a gauze covered test tube. Motionless in 13 minutes. Removed at 3 p.m. As they were found moving they were put back again (*vide* further)
2-30 p.m.		46	..	...
2-37 p.m.	3½ hrs.		45	Rat put in; ceased breathing in 20 minutes
2-40 p.m.	.		.	Mosquitoes introduced in a gauze covered test tube. All died at 3 p.m.
2-50 p.m.	..		N.E. lower corner 40	...
3-0 p.m.	4 hrs	..	...	Fleas that were put in at 2-22 p.m. were re-introduced into the chamber and allowed to remain there overnight.
Next day, 3-2-1925				
9-45 a.m.	22 hrs.	25	..	....
9-57 a.m.	....	..	25	Bugs put in. Removed at 10-37 a.m. found alive next day.
10-15 a.m.	....	..	26	....
10-40 a.m.	....	.	...	Bugs put in a wide mouth open bottle and introduced into chamber. Removed at 11-13. At 12-0 they were observed moving about.

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TABLE IV—*contd.*

Time at which test was started.	Period.	Parts of HCN per 100,000 at point *A*	*B*	REMARKS.
10–50 a.m.	....	..	21	Rat put in lowest compartment; unconscious at 11-13. Removed at 11-50 when it was gasping. Recovered on putting in fresh air.
11–15 a.m.	21 hrs.	..	....	Rat put in upper compartment; removed dead at 4-30 p.m.
11–45 a.m.	....	23	...	....
3– 0 p.m.	28 hrs.	17	....	....
Third day, 4-2-1925				
9–45 a.m.	....	4	..	....
10– 0 a.m.	47 hrs.	..	6	....
...	....	9	..	By means of a long glass rod the powder in the chamber was raked and concentration taken.

EXPERIMENT VIII.

This experiment was designed to imitate rat burrows.

An L-shaped channel was dug in the ground with arm *AB* 4 feet long and the arm *CB* 6 feet. The channel was 6 inches wide and about 6 inches deep; its sides were sloping so that its floor was about 3 inches broad. The top of the channel was covered with plate-glass and the channel made as air-tight as was possible by closing up crevices and openings with dry earth. On one side of the vertical arm a pit was dug and a cage with a rat so buried in it that one side of the channel was formed by the side of the cage. Thus the cage was in communication with the channel. By such an arrangement the rat in the cage and the rats that were subsequently introduced into the channel through *C* could be observed.

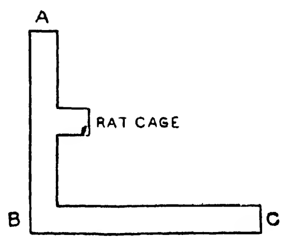

FIG. 1.

One ounce of calcium cyanide was sprinkled in the channel for about a foot length commencing at *A*. The results of this experiment are given in Table V.

TABLE V.

Experiment started 3-5 *p.m.*

Time at which test was started.	Period.	Point at which concentration was taken.	Concentration of HCN in parts per 100,000.	REMARKS.
3-20 p.m.	15 mins.	Above the powder.	250	At 3-5 rat was let in from *C* end. It ran up to *A* end, came back to *B*, and died in 3 minutes.
3-30 p.m	25 mins.	Near *C*	8	...
3-48 p.m.	43 mins.	Near *B*	46	...
4-30 p.m.	1½ hr	...	16	At 3 17 rat in the cage was seen alive. Alive also next day at 10 a.m.
4-40 p.m.	.	Midway between *A* and *B*	62	...
4-50 p.m	1¼ hr	At *A* end	385	At 3 20 third rat introduced through *C* end. It ran up to *A* end, returned to *C*, and died in about 5 minutes.
23-1-1925				
9-45 a.m.	18½ hrs.	*C* end	6	Rat introduced at 9 55 through *C* end, it ran up to *A* end and back to *C*. At 10 10 it ran up again to *A* end where, in about a minute, it was flattened. It was not able to run back.
		A end	76	
10- 0 a.m.	..	Angle	6	
10- 9 a.m.	..	....	....	Quarter ounce of calcium cyanide sprinkled opposite the cage.
10-30 a.m.	19½ hrs.	In the cage	51	Rat in the cage died at 10 40 a.m. This cage was removed and another with a live rat placed. Rat did not die.
10-48 a.m.	..	....	...	A rat introduced through the *A* end; unconscious in 2 minutes.
10-50 a.m.	.	At the dusted spot	38	....
1-45 p.m.	22 hrs.	At the dusted spot	10	....

From the results of this experiment it appears that there is little diffusion of hydrocyanic acid gas, i.e., there is high concentration at the spot where the calcium cyanide has been sprinkled, but there is little of the gas in the portion of the channel only one foot away from it. The rat in the cage was found alive at the end of 19 hours notwithstanding that it was in air which was in

direct communication with air showing a concentration as high as 385 parts of hydrocyanic acid gas per 100,000 of air.

EXPERIMENT IX.

This experiment was similar to the previous one but on a large scale, and with a device to blow fresh air into the channel with a view to mix the contained air. The channel was in the form of two L's joined together as shown in figure 2. Three cages with one rat in each were fixed up in three parts of the channel.

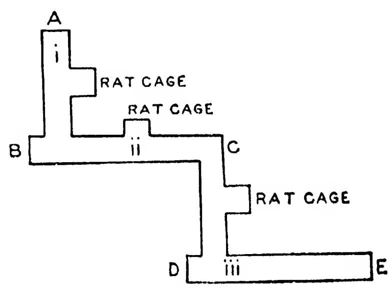

FIG. 2.

From *A* end air was pumped in occasionally. The details are given in Table VI.

TABLE VI.

Experiment started at 11-10 a.m.

Time at which test was started.	Period.	Point at which concentration was taken.	Concentration of HCN in parts per 100,000.	REMARKS.
11-10 a.m.	..	...	..	One ounce of calcium cyanide sprinkled on 2′ channel marked *i* at end *A*. From *A* end air pumped in for about 2 minutes.
11-13 a.m.	..	....	....	Rat let in from *E*, it ran up to *B* only and was alive till 2-25 p.m.
11-20 a.m.	..	....	....	Rat in cage 1, seen unconscious but still breathing; it ceased breathing in about 2 minutes more.
11-25 a.m.	..	....	....	Rat let in through *E* end; it ran up to *B* only and was alive till 2-25 p.m. From *A* end air pumped in again for about two minutes.
11-40 a.m.	½ hr.	*A*	384	....

TABLE VI *contd.*

Time at which test was started.	Period	Point at which concentration was taken	Concentration of HCN in parts per 100,000	REMARKS
11-50 a.m.	10 mins	*A*	570	
12- 0 noon.		*A*	530	Another rat put in through *E*; it ran up to *A* and back to *E*, ran up again to *A* where it fell and died in 3 minutes.
12-20 p.m.		*B*	9	..
1-30 p.m.	..	*B*	9	. .
1-40 p.m.	$2\frac{1}{2}$ hrs.	*A*	370	. . .
2-10 p.m.	.	Opp. and close to cage 1	5	. . . .
2-25 p.m.	.		. . .	One ounce of calcium cyanide distributed in about equal portions on spots marked *ii* and *iii* in the figure.
2-40 p.m.	$3\frac{1}{2}$ hrs.	. . .	.	Rats put in at 11-13 a.m. and 11-25 a.m. which were sitting quietly at *B*, died.
2-45 p.m.	..	Opp. cage 3	16	. . . .
2-54 p.m.	..	.	. . . .	Three rats introduced through *B*; of these two ran down to *O* and died in about 5 minutes. The third rat remained at *B* and died at 3-30 p.m.; during this period it did not change its position very much.
2-56 p.m.	.	Opp. cage 3	16	. . . .
3-15 p.m.	.	At *iii*	148	. . . .
3-14 p.m.		Opp. cage 2	270	. . . .
3-30 p.m.	4 hrs.	*E*	3	. . .
4- 0 p.m.	..	. . .	..	Air pumped in again through *D*.
4-30 p.m.	5 hrs.	. . .	. . . .	Rat in cage 3 still alive.
28-2-1925				
9-56 a.m.	3 hrs	*ii*	12	. . . .
10- 0 a.m.	..	*iii*	18	. . . .
10- 7 a.m.	..	*i*	24	All rats except that in cage 3 removed dead when the channel was opened up and the cages dug out.

This experiment demonstrated that the attempt to circulate air in the channel succeeded partially in diffusing the gas, e.g., the rat in cage 1 in Experiment VIII

was not killed though the gas was present in high concentration just beyond the cage. But the rat in the same position in this experiment was killed and this was due to pumping in air to diffuse the gas.

EXPERIMENT X.

Experiment similar to the last one. No pumping in of air done in this experiment.

Experiment started at 2 p.m.

Three-quarter ounce of calcium cyanide was spread in areas marked *i* and *ii* in fig. 2 and the remainder subsequently in the spot marked *iii*.

Results of this experiment are shown in Table VII.

TABLE VII.

Time at which test was started.	Period.	Point at which concentration was taken.	Concentration of HCN in part per 100,000.	REMARKS.
2- 0 p.m.	..	...	..	Powder sprinkled at *i* and *ii*. Rat in cage 2 ceased breathing in 5 minutes more.
2-10 p.m.	..	...	...	Rat put in through *E*; it ran up to *B*, returned to near *D* where it lay unconscious. Breathing at 2-12.
2-15 p.m.	15 mins.	*i*	610	....
2-30 p.m.	30 mins.	*i*	220	...
2-40 a.m.	40 mins.	Near *B*	10	...
2-48 p.m.	48 mins.	Near *D*	4	.
3- 0 p.m.	1 hr.	....	....	Put the rest of the powder at *iii*.
3-10 p.m.	1 hr. 10 mins.	*iii*	220	..

As there was no attempt made in this experiment to assist diffusion of the HCN, rat in cage 1 was not killed, as the high concentration zone was a short distance away from the cage. Rat in cage 2 died as the high concentration zone was just opposite to it.

EXPERIMENT XI.

This was similar to the two previous ones. Arrangements were made for circulation of air in the channel with a view to produce a more or less even concentration of HCN throughout the channel. The *A* end of the channel was connected

by means of 6 feet length of hose pipe with a Chapman Forge Fan. One ounce of calcium cyanide was used. Results are given in Table VIII.

TABLE VIII.

Time at which test was started.	Period	Point at which concentration was taken.	Concentration of HCN in parts per 100,000	REMARKS
11-45 a.m.				One ounce of powder sprinkled on spot marked *C*. Immediately after, fan was worked for about 2 minutes. During this, earth from the channel was seen being blown out to a certain extent at end *E*
12-0 noon				Fan worked again for 2 minutes.
12-5 p.m.	20 mins	Opp. cage 1	90	
1-30 p.m.	1 hr. 45 mins	Opp. cage 2	5	
1-31 p.m.		Opp. cage 2	6	Fan worked again.
1-45 p.m.	2 hrs.	I	263	
2-50 p.m.	3 hr	A	216	
		B	7	
		C	3	

In this experiment all the three rats in the cages were found alive demonstrating that hydrocyanic acid was not able to diffuse into the cages to maintain the lethal concentration required to kill rats.

EXPERIMENT XII.

By means of Experiments V, VI and VII, it was ascertained that one ounce of the calcium cyanide when spread out in a fairly air-tight space gave a concentration of 30 to 50 parts of hydrocyanic acid gas per 100 c. ft. of space.

Accordingly the following bell jar experiment was arranged. A glass-plate and bell jar used to keep microscopes free from dust were used in this experiment.

The cubic capacity of the bell jar was measured and found to be about two-thirds of a cubic foot.

A pad of cotton wool was fixed round the margins of the glass-plate upon which the bell jar rested.

(*a*) Between 0·1 and 0·15 grammes of calcium cyanide was spread out on a piece of paper placed in the centre of the plate. Over this a cage with one rat was put and the whole covered with the bell jar. The rat was seen to have a convulsive seizure after seven minutes, to gasp for three minutes more and cease to breathe after 13 minutes from the time of commencement of exposure.

(*b*) Instead of the fresh calcium cyanide, 3 grammes of the used cyanide was spread on the paper on the plate, a cage with a rat put on it, and the whole covered with the bell jar. Observations were made for half an hour and the experiment was given up as the rat was seen as lively at the end of this period as at the start.

(*c*) 0·3 grammes of fresh cyanide was spread on the paper; a cage with a rat put on this. This cage was of such a size that when it was covered with the bell jar, the brim of the jar did not touch the plate and there was an open gap about quarter inch all round between the plate and the brim of the bell jar. This kept a far freer communication between the air under the bell jar and that outside it, than in experiments (*a*) and (*b*). Under these circumstances, notwithstanding the quantity of cyanide, which should have given a concentration of 100 parts per 100,000 of air, a lethal concentration was not maintained and the rat was not affected even after exposure for half an hour.

These three experiments confirm the fact that a lethal effect is attained only on maintaining a certain minimum concentration for a certain minimum period, which conditions are attainable mainly in a closed space

SUMMARY

For fumigation purposes, hydrocyanic acid gas is ordinarily generated by mixing together solutions of sulphuric acid and potassium or sodium cyanides involving the use of special apparatus, while in the case of calcium cyanide no such apparatus is required as the mere exposure of the material to the air evolves the gas.

The efficacy of hydrocyanic acid gas in killing rodents and insects depends upon two factors, the concentration of the gas (30 to 50 parts per 100,000 of air being the minimum) and the period of exposure (the minimum being ½ to 1 hour), these two conditions are such that they are obtainable only in fairly air-tight spaces

Experiments II to IV were performed in the open -IV being in a space which was not air-tight though covered up- with the result that the insects exposed to the cyanide were not killed. Similarly experiment XII (*c*) shows that lethal concentration was not attained even though the quantity of cyanide sprinkled in the space was nearly three times that required for lethal concentration.

Experiments V to VII which were performed in a fairly air-tight space (viz., the fumigation chamber) showed that lethal concentrations were attained and when rats and insects were exposed for a sufficient period they were killed.

Experiments VIII to XI were instituted to imitate the effect of calcium cyanide in rat burrows. These experiments showed that there was little diffusion of the gas in narrow channels. High concentrations (e.g., 300 per 100,000) prevailed only at the place actually dusted with cyanide, while in the air spaces closer by, the concentrations were hardly above 5 to 10 parts.

Experiment XII (*a*) showed that calcium cyanide when spread in closed spaces at the rate of 1 ounce per 100 c. ft. of space produces a lethal concentration; XII (*b*) showed that exhausted calcium cyanide even used in quantities 30 times more than the required one failed to affect the rat; XII (*c*) showed that unless calcium

cyanide is used in closed (i.e., air tight) spaces, lethal concentration is not attained even though the quantity used is three times more than the required one.

Conclusions.

1. The use of calcium cyanide for the generation of hydrocyanic acid gas for fumigation purposes is much simpler and more convenient than that of sulphuric acid and the cyanide of potassium or sodium.

2. The mere exposure of calcium cyanide to the air results in evolution of most of the hydrocyanic acid gas in about 1½ hour.

3. For hydrocyanic acid gas to be effective two factors are required, viz., a minimum concentration of the gas in the air and time of exposure. These conditions are only attainable in fairly air-tight spaces.

4. One ounce of calcium cyanide when used per 100 c. ft. under the condition laid down in 3 gives a lethal concentration which is attained in about 1½ hour and maintained for about 4 hours.

5. If calcium cyanide is used in the open, or even in spaces not made sufficiently air-tight, lethal concentraion is not attained, and there is failure to kill insects and rodents.

6. Diffusion of hydrocyanic acid gas generated from the calcium cyanide sprinkled in narrow channels dug out in the ground, was too poor to be effective all along the channel.

Cyanogas Calcium Cyanide For the Control of Insects Infesting Grain in Storage Bins

By

Gilbert Schenk, Entomologist;

American Cyanamid Company

INTRODUCTION

Grain, such as wheat and corn, is frequently stored in large bins for a considerable length of time. These bins are constructed of concrete, steel, brick, or wood. A series of such bins is referred to as a grain elevator in the United States. In the leading wheat areas of the United States, the farmer, after thrashing his grain, either stores it for a time on his farm or hauls it to the nearest town where it is placed in a small shipping elevator usually referred to as a country elevator. Directly after harvest these country elevators quickly become filled with grain and it becomes necessary for them to ship this grain to the large terminal elevators located at a number of central points. The terminal elevators store this grain until such time as it is to be shipped to the miller or in some cases to the export elevators. Some grain moves directly from the country elevator to the export elevator. The export elevators are large elevators located at the important shipping ports which hold the grain pending its shipment to foreign countries. During recent years some of the larger milling firms have erected their own storage elevators. After the main movement of the grain, directly after harvest, the terminal elevators and the export elevators may be filled with grain and it becomes necessary for the country elevators to hold the grain for a certain period of time. From these different methods of handling the grain it will be seen that from the time of harvest until the grain is milled or shipped out of the country it is stored in large bins for a considerable period of time, sometimes for as long as one or two years. During this period of storage there is often considerable loss, due to the attack of various insects.

LOSSES CAUSED BY INSECTS IN STORED GRAIN

The principal insects which have been encountered in these investigations and which are largely responsible for the losses sustained in the United States are as follows:

*Granary Weevil (*Sitophilus granarius* L.)
Rice Weevil (*Sitophilus oryza* L.)
Confused Flour Beetle (*Tribolium confusum* Fab.)
Rust Red Flour Beetle (*Tribolium ferrugineum* Fab.)
Saw Tooth Grain Beetle (*Silvanus surinamensis* L.)
Flat Grain Beetle (*Crypturgus pusillus* Gyll.)
Lesser Grain Borer (*Rhyzopertha dominica* Fab.)

In general the elevator man divides these insects into two classes—weevils and "bran bugs"; any insect other than a weevil is referred to as a "bran bug". The flour beetles, (*Tribolium* spp.) are really not injurious to whole wheat but are scavengers, feeding upon broken kernels and chaff. Millers, however, object to buying wheat infested with flour beetles since these insects are serious pests of milled grain products.

In addition to the insects listed above, the Angoumois Grain Moth, *Sitotroga cerealella* Oliv. and the Cadelle, *Tenebrioides mauritanicus* L. should be mentioned as important and serious pests of stored grain. These two species, however, were not present in any of the grain fumigated in our experiments.

The actual economic loss resulting from the activity of these grain insects may be summarized as follows:

1. If grain is not infested with insects and has a proper moisture content, it may be stored indefinitely without a rise in temperature. Infested grain put in storage shows a rise in temperature due to the activity of the insects (2).† When the temperature rises it becomes necessary to move the grain from one bin to another, thus aerating it to reduce the temperature. In general it is necessary to move infested grain every month or six weeks. Some elevators have a fixed charge of 1/8 of a cent per bushel for moving the grain from one bin to another, whether for this purpose or any other purpose.

2. The insects eat certain portions of the grain, thus causing a shrinkage in the weight. This is a definite loss to the man who holds the wheat at the time that the insects are actively at work. Wheat is sold on the basis of weight

*All of these specimens except *S. granarius* and *S. surinamensis* were determined by Dr. E. A. Back of the United States Department of Agriculture.

†Figures in parentheses refer to literature cited.

bushels, not volume bushels. The shrinkage in weight may be from one to five per cent during the first month of storage, and may increase in later months to a maximum shrinkage of ten per cent. A shrinkage in weight automatically places the grain in a lower grade. The minimum weight for the different grades of wheat as defined by the Federal Grain Board is as follows:

Grade	Hard Red Winter Wheat and Durham Wheat	Hard Red Spring Wheat
No. 1	60 pounds	58 pounds
No. 2	58 "	57 "
No. 3	56 "	55 "
No. 4	54 "	53 "
No. 5	51 "	50 "

3. Chaff, weed seeds, shrivelled or broken kernels, and other foreign material make up what is known as "dockage". The feeding habits of the insects naturally increase the quantity of broken kernels, thus increasing the percentage of "dockage". Wheat which is high in "dockage" must be so stated. The minimum "dockage" for the different grades is as follows:

No. 1	2%
No. 2	4%
No. 3	7%
No. 4	10%
No. 5	15%

Although the weight of the wheat might place it in a certain class, if the "dockage" exceeds the above percentage for that class, it is forced into the next lower class.

4. If more than one live weevil or more than two live "bran bugs" are found in a kilogram sample of wheat by a State or Federal Inspector, the grain is classed as weevily wheat. Such wheat must be freed of live insects or sold as weevily wheat at a discount of one cent per bushel.

5. Certain grain insects feed only on the carbohydrate portions of the kernel. In milling such wheat there is a loss sustained by the miller, inasmuch as a smaller amount of flour may be milled from a bushel of such wheat. Uninfested wheat will mill 65 to 75 per cent of flour. Wheat which has been subject to the attack of insects may not mill more than 40 per cent of flour.

The losses mentioned above are recognized by all of those who handle grain in storage. It is not so well recognized that grain frequently comes into storage infested with the insects. The infestation by the rice weevil and the angoumois moth frequently begins in the field, in the shock, or in the stack. During years when the weather conditions are such that the grain must be held for long periods in the shocks or stacks the infestation of these two species will increase to considerable proportions. Back and Cotton (1) have shown that as much as 6 per cent of the newly-thrashed wheat coming to the Baltimore market from the Maryland farms is already infested with the rice weevil. It has also been observed in the middle west that grain coming from the southwestern farms is infested. During a transportation tie up it has been observed, when cars of wheat from the Southwest are held for a month or longer during warm weather, that nearly every car is infested. Infested wheat may be unwittingly mixed with uninfested grain either in moving into or after it has reached the storage centers.

NEED OF AN EFFECTIVE METHOD OF INSECT CONTROL

Probably the only fumigant which has been extensively used for the destruction of insects infesting grain is carbon disulphide. The difficulties in the use of this material have been clearly stated in the following quotation (6): "It has an extremely disagreeable odor and in moderate concentrations its vapor is poisonous to man. Although carbon disulphide is volatile, millers occasionally complain that wheat which has been treated with it retains its odor, and it has been shown that the baking quality of flour from carbon disulphide fumigated wheat is sometimes injured.

"The really serious objection to the use of carbon disulphide as a fumigant, however, arises from the fact that it is readily inflammable and that its vapor when mixed with air is highly explosive. For this reason insurance companies refuse to carry the fire risk on elevators during the time carbon disulphide is being used to treat the grain contained in them."

It should be noted that Dean and Swanson (4) found that the baking qualities of wheat flour was not materially effected by fumigation with carbon disulphide at the maximum strength employed in flour mills and elevators.

An effort was made to overcome the disadvantages of carbon disulphide by mixing carbon tetrachloride with it but

the General Managers Association of Chicago, representing the leading railway systems of the United States, adopted resolutions prohibiting the use of this mixture, due to its highly inflammable character. At the same time, they requested the U. S. Department of Agriculture to undertake an investigation in order to find a substance which might be safely used for grain fumigation. The U. S. Department of Agriculture conducted such an investigation and published their results (6). In the course of this work, the possibilities of over one hundred organic compounds were studied. The most promising material was ethyl acetate. They found that under practical fumigation conditions, the efficiency of ethyl acetate was increased by mixing it with carbon tetrachloride. They learned that (6) "Odoriferous constituents of low volatility from commercial grades of ethyl acetate (both the 85 per cent and the 99 per cent grades) are carried through from the fumigated wheat to the flour, and even to the bread baked from it. A pure grade of ethyl acetate, however, leaves practically no odor in the fumigated grain or in the bran or shorts made from the grain; and none in the flour or in the bread baked from the flour."

The mixture of ethyl acetate and carbon tetrachloride has not come into general use, possibly for several reasons. These reasons have been summarized by Back and Cotton (3). "Since the ethyl acetate-carbon tetrachloride mixture is no more effective than carbon disulphide, leaves an odor on the grain, and in some respects is not quite so satisfactory from a toxicity standpoint under all conditions, it remains for the individual to determine whether its greater cost affects the advantage of freedom from fire hazard." Because of the low flash point of this mixture some insurance underwriters have withheld their approval.

During 1923 and 1924, the American Cyanamid Company conducted a series of experiments in an attempt to use liquefied hydrocyanic acid for the fumigation of grain elevators. Some difficulty was encountered in obtaining a uniform penetration of the fumigant throughout the mass of grain. Since the hydrocyanic acid gas killed the insects which it reached, it was thought that the difficulty of penetration could be overcome by distributing Cyanogas Calcium Cyanide evenly throughout the bin of grain.

PRELIMINARY EXPERIMENTS WITH CYANOGAS

In the preliminary experiments, fumigations of one bushel lots of wheat were carried out in galvanized iron ash cans. Kills were determined on insect-infested grain enclosed in perforated cardboard pill boxes. The following method of procedure was used. The first box of insects was placed in the bottom of the ash can and a stream of wheat was allowed to pour into the ash can from a bushel measure. At the same time, Cyanogas G-Fumigant was fed into the wheat stream by means of a funnel. The stream of wheat and the stream of Cyanogas were so regulated as to obtain an even distribution of the two materials. Pill boxes containing live insects and wheat were dropped into the wheat from time to time, the last pill box being so placed that it was just covered with wheat. The lid was then placed on the can and was left for the duration of the exposure. The boxes were removed at the close of the fumigation. The insects were examined under a lens and any which exhibited signs of life were recorded as alive and discarded. A further examination was made at the end of a twenty-four hour period. Such insects as then showed signs of life were recorded as stupefied and the balance recorded as dead. This twenty-four hour period was chosen after it was found that results were no different than those observed at the end of a seven-day period. Check boxes placed in untreated wheat showed 0 to 23 per cent dead insects, the average being 6 per cent. Samples of one kilogram of untreated and treated wheat were set aside in two-quart mason jars for emergence records. The glass tops were placed on the jars but the jars were not sealed. The results which were obtained in these experiments indicated that grain insects could be controlled with a dosage of Cyanogas which was economically practicable. (Table III)

The effect of this treatment upon the wheat was the next question to be considered. It was already known that fumigation of grain and flour in mills with hydrocyanic acid gas had no detrimental effect on these products. (4) Tests were made to determine if there would be any different effect when hydrocyanic acid gas was liberated in close proximity to the wheat kernels. Chemical analysis of the wheat and the various milled products indicated that the residual hydrocyanic acid in the wheat was insignificant, the bulk of this being found in the bran after milling. The flour showed only a trace. Baking tests were also made which indicated that

TABLE III

Results of Small Laboratory Experiments—Kansas City, Mo., 1926.

Expt. No.	Exposure Days	Cyanogas Lbs. per 1000 bu.	Room Temp. F.	Rel. Hum. %	Moisture of Wheat	Weevil			Bran Bugs			Emergence Live Insects	
						Alive %	Dead %	Stupefied %	Alive %	Dead %	Stupefied %	Untreated	Treated
101	1	15.5	75°F.	27%	12 %	0	100	0	0	100	0	38	0
102	1	19.9	75	27	12	0	100	0	0	100	0	30	0
103	1	15.5	74	35	18.37	25	35	40	8.4	67.9	23.7	0	0
104	1	19.9	74	29	21.55	35	20	45	15	52.5	32.5	0	0
105	1	22.1	66	35	16.96	35	55	10	72	24	4	8	0
106	1	22.1	66	35	16.15	20	40	35	12	52	32	150	0
107	1	22.1	66	35	14.51	0	45	55	0	72	28	14	0
108	1	22.1	66	35	15.88	40	45	15	24	48	28	22	0
109	1	22.1	66	35	11.56	0	70	30	0	100	0	18	0
110	1	26.5	70	32	15.90	0	70	30	0	100	0	35	0
111	1	26.5	70	32	14.81	0	100	0	0	100	0	19	0
112	1	26.5	70	32	13.62	0	100	0	0	100	0	22	0
113	1	26.5	70	32	12.39	0	100	0	0	100	0	20	0
114	1	26.5	70	32	11.50	0	100	0	0	100	0	20	0
115	1	19.9	80	29	12.60	0	85	15	0	100	0	14	0
116	1	19.9	80	29	14.05	0	80	20	0	100	0	21	0
117	1	19.9	80	29	15.45	0	96	4	0	100	0	41	0
118	1	19.9	80	29	14.95	0	96	4	0	100	0	38	0
119	1	19.9	80	29	14.17	0	96	4	0	100	0	19	0
120	1	28.1	78	30	19.73	10	25	65	0	100	0	0	0
121	1	28.1	78	30	19.82	55	30	15	0	100	0	0	0
122	1	28.1	78	30	19.90	35	40	25	0	100	0	0	0
123	1	22.1	74	32	10.2	0	95	5	—	—	—		
124	1	22.1	74	32	10.2	0	72.5	27.5	—	—	—		
125	1	22.1	74	32	10.2	0	67.7	32.3	—	—	—		
126	1	22.1	74	32	10.2	0	82.5	17.5	—	—	—		
127	7	15.5	76	30	10.2	0	100	0	—	—	—		
128	7	15.5	76	30	10.2	0	100	0	—	—	—		
129	7	15.5	76	30	10.2	0	100	0	—	—	—		
130	7	15.5	76	30	10.2	0	100	0	—	—	—		
131	7	11.1	76	30	10.2	0	100	0	—	—	—		
132	1	15.5	64	35	11.0	0	60	40	—	—	—		
133	1	15.5	64	35	16.01	5	70	20	—	—	—		
134	1	15.5	64	35	13.66	0	75	25	—	—	—		
135	1	15.5	64	35	12.77	0	40	60	—	—	—		
136	1	15.5	64	35	13.52	0	30	70	—	—	—		

NOTE:—One bushel of wheat fumigated in each experiment.

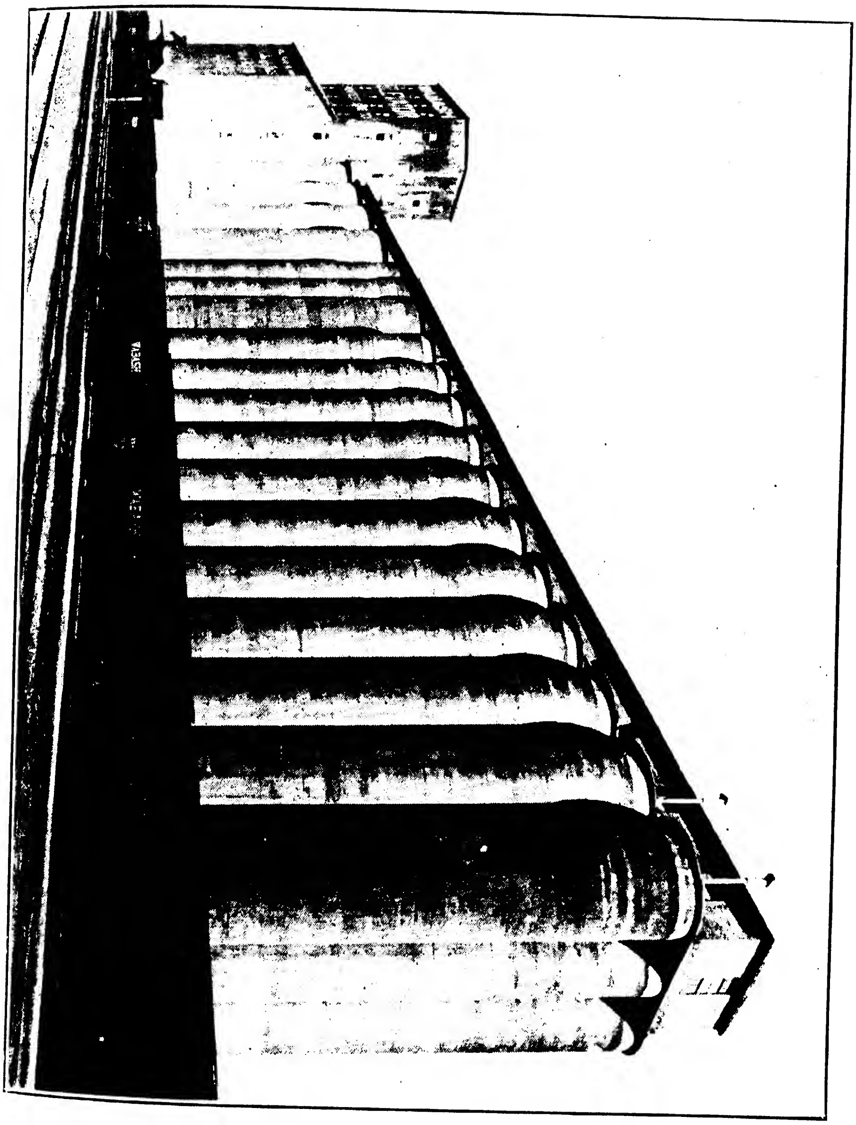

Fig. 1-3. Elevator in Which Commercial Experiments Were Conducted.
Note Outside Vents, Top of End Bins.

there was no difference between treated and untreated wheat. Having obtained these promising results, it was decided that the experiments should be continued on a large-scale, commercial basis.

EXPERIMENTS ON A COMMERCIAL BASIS

Arrangements for experimental work were made with one of the large companies in Kansas City, Missouri. Their elevator consisted of a series of large concrete bins with a total capacity of 950,000 bushels. The individual bins varied in capacity from 3,800 to 25,000 bushels. (Fig. 1-3)

Application of the Fumigant

From previous experience in the small-scale experiments, it was decided that the best method of applying the Cyanogas would be to mix it with the stream of wheat at the top of the bin as the bin was being filled. A hopper with a roller feed was devised for this purpose. In some of the early experiments, the roller of this hopper was turned by a system of pulleys and bevelled gears tapped from the shaft of one of the conveyor belt rollers. (Fig. 2-3) Under this system the machine was in operation only when the conveyor belt was running. However, there was a disadvantage in that the device was fixed to the spout only on one side of the conveyor belt. In order to obtain a more flexible arrangement, an electric motor was mounted on a shelf attached to the hopper and power was derived from it by a system of cone pulleys and worm reduction gears. (Fig. 3-3)

The non-sparking motor used in these experiments had the following specifications:

Motor
General Electric Company
Model No. 20001
Type S. A.
Frame 145 — Form S 1
Volts 110
Amperes 4.2
Horse Power 1/6 Speed 1725
Cycle 60 Single Phase
Temp. Rise—40° C.
Time Rating — Continuous
No. 3563444

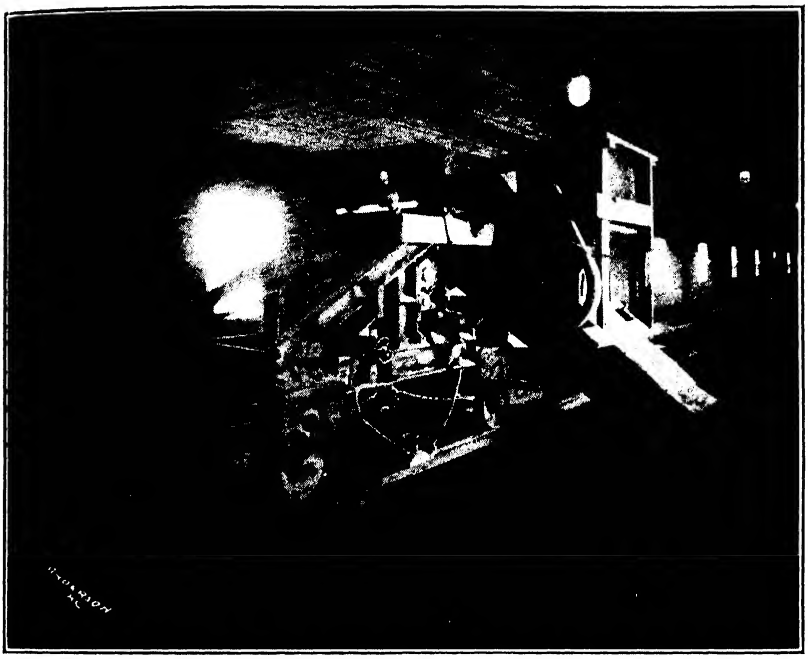

Fig. 2-3. Original Hopper with Roller Driven from the Tripper.

The speed of the motor was reduced by means of a 48 to 1 reduction gear. Attached to the shaft of the motor was a grooved cone pulley of the following diameters: 1″, 1⅛″, 1¼″. Mounted on the shaft of the worm gear was a 4″ grooved pulley. The driving pulley attached to the roller caused the roller to revolve at the same rate. The roller was made of well-seasoned maple, free of blemishes. The ends of the roller were strengthened by ¾″ x ¼″ steel bands. The body of the hopper was made of 16 gauge steel with angle iron used as the frame. A sliding steel bar with adjusting screws provided for adjusting the opening between the roller and the edge of the hopper. When the speed of the wooden roller remained constant, the amount of Cyanogas fed per hour was regulated by adjusting this slide to the desired amount. It was found that the preferable way to regulate the feed was to keep the opening of the slide constant and change the speed of the roller so that the number

Fig. 3-3. Standard Cyanogas Hopper with Roller Driven by Electric Motor.

of revolutions were increased or decreased. It was found that if the opening between the slide and the roller was 1/16th of an inch and if the belt was on the one and one-eighth inch pulley of the motor, the speed was approximately 30 revolutions per minute. This fed the G-Fumigant at the rate of approximately 125 pounds per hour. When it was desired to feed 100 pounds per hour, the belt was changed to the one

inch pulley or to the one and one-quarter inch pulley if 150 pounds per hour was needed. Further adjustments to give the exact dosage were made by slight modifications of the opening between the slide and the roller.

A detail method was used to determine the rate at which the Cyanogas was being fed into the wheat. The proper adjustments were made and the motor started. A dust pan or other convenient receptacle, wide enough to reach across the entire width of the roller, was used to catch the Cyanogas passing through the slot for one minute. The Cyanogas was weighed and calculation made to give the amount which would be fed in one hour.

The other variable which had to be considered was the rate at which the wheat flowed into the bin. The wheat moves to the bin on a conveyor belt where it is discharged by the tripper into the bin. (Fig. 4-3) The rate at which the wheat is carried on the conveyor belt depends on a number of variable factors. This rate usually varies from four to six thousand bushels per hour. The weighmaster estimated the rate at which the wheat was flowing on the belt. The amount of Cyanogas which was applied per hour depended upon this estimate of the wheat flow.

The Cyanogas G-Fumigant was fed directly into the stream of wheat, at, or as near as possible to, the manhole. It was found desirable to have a canvas cover placed around the stream of wheat, extending from the spout of the tripper to the manhole. The Cyanogas was fed directly into the stream of wheat through a hole in this canvas. (Fig. 5-3) The canvas cover was used to prevent the displaced air of the bin carrying hydrocyanic acid into the room above the bins. It was also found desirable to arrange for an outside vent to the bin for carrying off the displaced air. This outside vent was in the form of an eight inch pipe leading from the roof of the bin to the roof of the enclosure above the bin. The outside end of this vent was provided with means of protection against rain. (Fig. 1-3—End Bins.)

Effect of Fumigation on the Insects

Preliminary experiments indicated that a satisfactory kill could be obtained with a dosage of 7 to 12 grams per bushel. This is equivalent to a dosage of 15 to 26 pounds of Cyanogas to 1,000 bushels of wheat. Experiments on a commercial

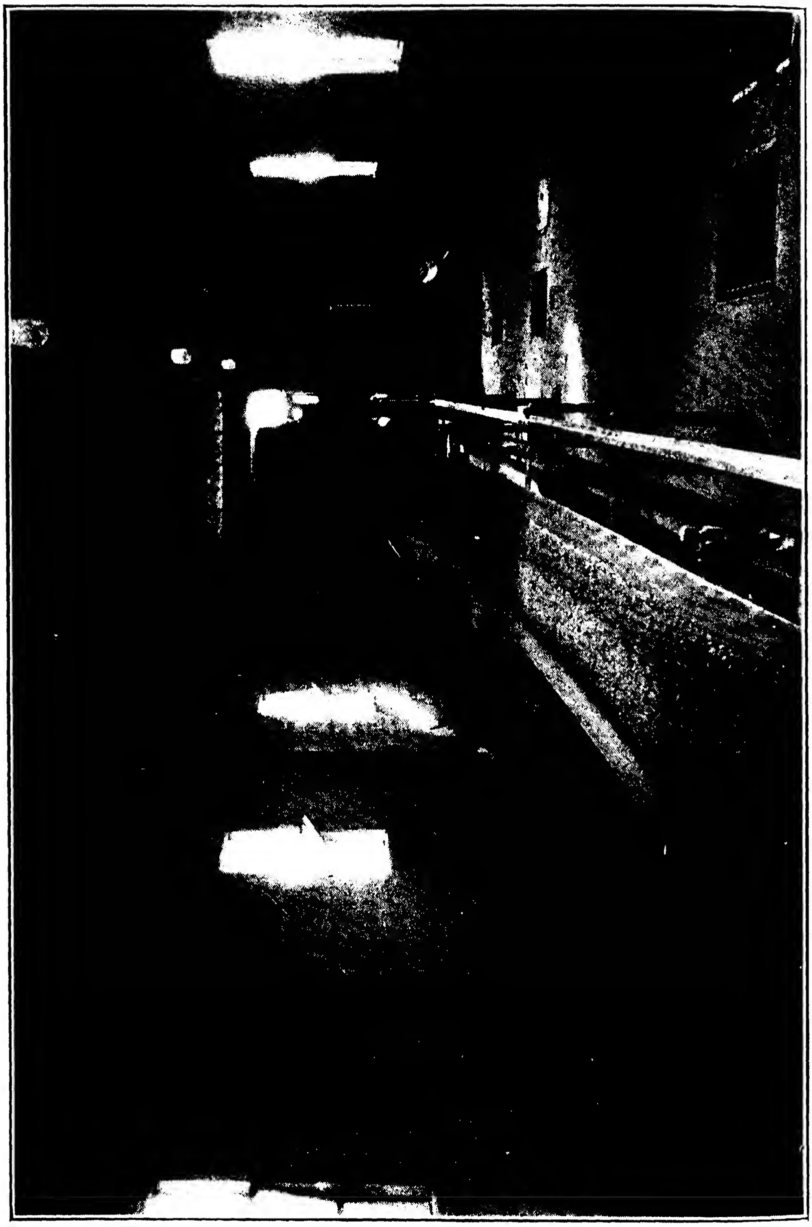

Fig. 4-3. Wheat Moving Toward the Tripper on the Conveyor Belt. Cyanogas Hopper in Position in Background.

TABLE IV

Results of Commercial Fumigations—Kansas City, Mo., 1926.‡

Expt. No.	Exp. Days	Cyanogas Lbs. per 1000 bu.	Room Temp.	Rel. Hum.	Moisture of Wheat	Temp. of Wheat	WEEVIL						BRAN BUGS					
							DEAD		STUPEFIED		ALIVE		DEAD		STUPEFIED		ALIVE	
							Above the Wheat	In the Wheat	Above the Wheat	In the Wheat	Above the Wheat	In the Wheat	Above the Wheat	In the Wheat	Above the Wheat	In the Wheat	Above the Wheat	In the Wheat
10	1	20	50°F	45%	12 %	60°F.	—	92	—	1.9	—	4.6	—	—	—	—	—	—
x 11	1	19.5	65	30	13.6	65	88.7	93.6	7.5	6.3	3.7	0	—	—	—	—	—	—
1	1	20.0	50	45	12.0	60	—	92.9	—	1.9	—	4.6	—	—	—	—	—	—
3	1	20.7	42	53	14.5	60	92	90	4	1.6	4	8.3	—	—	—	—	—	—
5	1	21.6	32	50	13.8	58	—	90	—	10	—	0	—	—	—	—	—	—
7	1	22.3	60–62	45	14.0	65	77.5	84.5	12.5	15.5	10	0	—	—	—	—	—	—
14	1	23.2	38	75	13.2	50	100	72.5	0	26.1	0	1.2	—	—	—	—	—	—
8	1	23.3	65	45	14.0	65	90	79	10	21	0	0	—	—	—	—	—	—
37	1	24.2	68	57	12.4	60	66	91.8	34	8.2	0	0	—	—	—	—	—	—
40	1	24.2	65	45	12.4	60	85	90.8	15	9.2	0	0	—	—	—	—	—	—
x 12	1	25.6	44	38	13.2	48	90	41.4	10	47.1	0	11.4	100	99.0	0	1	0	0
6	1	27.1	32–33	52	14.0	56	—	97.1	—	2.9	—	0	—	—	—	—	—	—
18	1	27.7	60	39	11.0	80-90	—	70.2	—	25.6	—	4.1	—	—	—	—	—	—
9	1	30.9	63	47	14.2	65-82	—	88.3	—	10.8	—	0.8	—	—	—	—	—	—
13	1	43.9	38	44	13.0	44	98	98.6	2.0	1.4	0	0	100	83.1	0	16.9	0	0
2	2	17.5	60	40	15.0	66-88	—	100	—	0	—	0	—	—	—	—	—	—
16	2	19.8	48	49	12.8	50	38.0	43.3	42.8	56.6	19.0	0	—	—	—	—	—	—
38	2	23.9	68	57	12.4	60	60.0	86.0	40.0	15.0	0	0	—	—	—	—	—	—
17	2	24.0	48	49	12.8	50	70.7	71.0	29.2	29.0	0	0	—	—	—	—	—	—
15	2	24.1	38	65	13.6	40	—	71.3	—	26.6	—	2	—	—	—	—	—	—
19	2	24.7	60	43	12.0	70	—	64.0	—	36.0	—	0	—	—	—	—	—	—
4	2	26.	36	70	14.0	42	95	84.3	0	2.1	5	14.2	—	—	—	—	—	—
24	3	20.2	57	36	13.8	62	100	91.1	0	8.8	0	0	100	100	0	0	0	0
25	3	21.8	68	46	13.0	50	58.3	90.0	41.6	0	0	10.0	100	100	0	0	0	0
*26	3	23.3	67	62	15.4	—	—	70.8	—	29.1	—	0	—	100	—	0	—	0
39	3	25.	65	39	13.4	54	—	97.5	—	2.5	0	0	—	—	—	—	—	—
27	3	25.4	58	61	12.0	60	80	100	20	0	0	0	100	100	0	0	0	0
32	3	25.5	63	26	12.0	60	100	100	0	0	0	0	100	100	0	0	0	0
35	3	26.2	76	28	12.4	70	95	100	5	0	0	0	100	100	0	0	0	0
28	3	26.9	58	61	12.0	55	—	92.3	—	7.6	—	0	—	100	—	0	—	0
21	4	18.1	68	46	12.8	55-85	100	91.0	0	0.9	0	7.9	100	100	0	0	0	0
20	4	21.3	55	37	11.8	80-110	—	100	—	0	—	0	—	100	—	0	—	0
22	4	21.6	67	45	12.2	65-100	82.7	89.8	17.2	2.5	0	7.6	100	100	0	0	0	0
36	4	25.8	75	30	12.0	70	100	100	0	0	0	0	100	100	0	0	0	0
33	4	27.8	75	34	12.0	65	100	100	0	0	0	0	100	100	0	0	0	0
*29	7	23.5	67	45	16.8	60	—	100	—	0	—	0	—	100	—	0	—	0
(-)31	7	25.3	60	39	12.4	60	—	100	—	0	—	0	—	100	—	0	—	0
30	7	26.3	67	45	12.0	65	100	100	0	0	0	0	100	100	0	0	0	0
34	7	27.2	74	46	12.4	58	100	100	0	0	0	0	100	100	0	0	0	0

‡ Total number of bushels fumigated, 167,831; individual experiments ranged from 1700 to 10,600 bushels.
* No. 6 and 29 was fumigation of corn instead of wheat.
(-) No. 31—Fumigation in wooden bin instead of concrete bin.
x No. 11 and 12—Fumigation with Cyanogas "A" Dust instead of "G" Grade.

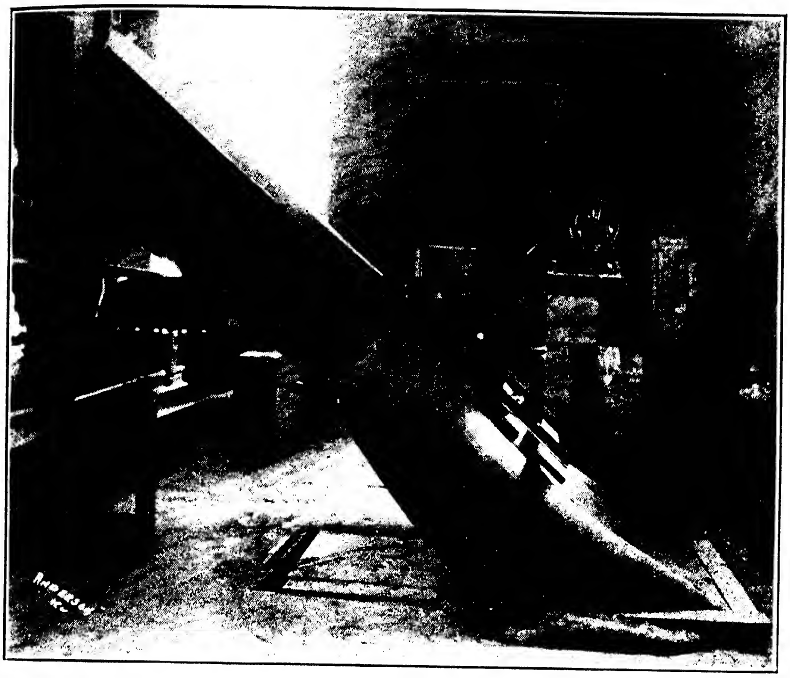

Fig. 5-3. Hopper in Position on Tripper Spout. Note Canvas Cover Around Stream of Wheat.

basis were conducted with dosages within or near this range. The kill was determined from insects enclosed in perforated cardboard pill boxes or in metal salve boxes with screen ends in a manner similar to that used in the preliminary experiments. One difference might be noted. In the preliminary experiments the boxes contained insects and wheat while in the commercial experiments only insects were placed in the boxes. This change was necessary to prevent the insects being injured by the wheat since the boxes rolled about when the bin was filled or emptied. In some of the experiments the insect boxes were enclosed in perforated containers attached to cables suspended at the sides and center of the bin. This method was used to make sure that there was no difference in kill in any part of the bin. (Table IV)

When heavily infested wheat was used, samples were taken at regular intervals while the bin was being emptied. These samples were examined following the standard method employed by State and Federal Inspectors. (Table V)

TABLE V

Commercial Inspections of Fumigated Grain
Kansas City, Mo., 1926.

Expt. No.	Exposure Days	Cyanogas Lbs. per 1000 bu.	Live Weevil and Bran Bugs Before		After
14	1	23.2	0		0
18	1	27.7	850		1
9	1	30.9	200-250		0
13	1	43.7	4		0
16	2	19.8	2		0
15	2	24.1	0		0
19	2	24.7	3		0
24	3	20.2	0		0
28	3	26.9	2		0
21	4	18.1	190		0
20	4	21.3	1544		1
22	4	21.6	291		2
			1 Bushel Lots		
			Before	After	
				Dead	Alive
123	1	22.1	202 live insects	54	None
124	1	22.1	counted in 1 bushel	41	None
125	1	22.1	of same wheat before	69	None
126	1	22.1	treatment.	55	None

Additional samples were taken from the top, center and bottom of the bin. These samples were set aside for two months in glass jars, covered with wire gauze for determination of emergence. Similar types of samples were taken of the same wheat in all experiments before fumigation to serve as a check. The results of these experiments are recorded in Table VI.

In fumigations for a period of one day, a difference is noted in the kills of insects contained in pill boxes as compared with that obtained of insects left in the wheat. It was found that there was sufficient gas present in the wheat at the end of a twenty-four hour fumigation to stupefy live weevil placed in the wheat. Therefore, insects present in the wheat would be exposed to this low concentration of hydrocyanic acid gas for a certain period of time after the wheat was removed from the fumigation bin. Insects contained in the pill boxes were entirely removed from the grain at the end of the twenty-four hour period. Such insects had a better opportunity of reviving than those present in the wheat. If elevator practice was

TABLE VI
Emergence Records

	From Untreated Wheat						From Treated Wheat					
	Weevil			Bran Bugs			Weevil			Bran Bugs		
Expt. No.	Top	Center	Bottom	Top	Center	Bottom	Top	Center	Bottom	Top	Center	Bottom
1	0	1	1	0	0	0	0	0	0	0	0	0
2	21	7	15	1	50	20	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0
4	0	0	1	0	0	0	0	0	0	0	0	0
5	5	5	10	2	0	2	0	0	0	0	0	0
6	2	1	1	0	0	0	0	0	0	0	0	0
7	0	0	0	0	3	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	22	19	10	0	3	0	0	0	2	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	1	0	1	1	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0

such that fumigated wheat would be handled so that the insects would be exposed to these low concentrations for a few days longer, the twenty-four hour fumigation could be recommended. However, fumigated wheat may be loaded into cars with unfumigated wheat immediately after treatment. Such mixing reduces the low concentration to a point where stupefied insects may revive. To overcome this difficulty, the fumigation period was increased to a point where complete kills were obtained in the pill boxes. This gave a minimum fumigation period of seventy-two hours, sufficient for satisfactory results regardless of how the wheat was handled at the close of the fumigation. An examination of the tabulated results will show that complete kills were obtained with dosages as low as twenty pounds per 1,000 bushels of grain. Inasmuch as there may be a certain amount of error in the estimate of the rate at which the wheat flows into the bin, it was decided to recommend a dosage of twenty-five pounds per 1,000 bushels.

In the experiments in which the boxes of insects were suspended on cables no difference in the kill was found between those at the side, center, top or bottom. It was noted, however, in certain experiments where wheat was run into empty bins that the pill box which dropped into the cone-shaped bottom of the bin showed a certain number of live or stupefied insects. The following tabulation of Experiment No. 22 brings out this point.

Experiment No. 22

General weather conditions
High Temp.—73° F.
Low Temp.—45° F.
Mean Temp.59° F.
Precipitation 7 A.M. to 7 P.M. = 00
Relative Humidity

7 A.M.	Noon	7 P.M.
71%	49%	45%

Check boxes every 5 minutes.
No Cyanogas dropped at start

Filled 4/16/26—9:10 to 9:50 P.M.
Emptied 4/20/26—10:00 to 11:00 P.M.
Room Temp.—67° F.
Relative Humidity—44%
Wheat Temp. 65—100° F.
Moisture content—12.2%

Dosage

2675 Bu. Wheat @ 55.5lb per bu.
58lb Cyanogas used. 21.6lb per 1000 bu.

Cage	No. Weevil Alive	Dead	Stupefied	Cage	No. Bran Bugs Alive	Dead	Stupefied
1	6	4	0	1	0	6	0
2	0	10	0	2	0	13	0
3	0	11	0	3	0	15	0
4	0	10	0	4	0	12	0
5	0	10	0	5	0	14	0
6	0	10	0	6	0	16	0
7	0	9	0	7	0	9	0
8	0	7	2	8	0	20	0
	6	71	2		0	105	0

To overcome this difficulty, two pounds of Cyanogas G-Fumigant were dropped into an empty bin before any wheat was run into the bin. Experiment No. 32 which was conducted with this procedure is presented in detail and should be compared with the preceding experiment.

Experiment No. 32

General weather conditions
High Temp.—64°F.
Low Temp.—42°F.
Mean Temp.—53°F.
Precipitation 7 A.M. to 7 P.M. = 00
Relative Humidity

7 A.M.	Noon	7 P.M.
52%	38%	36%

Filled 4/28/26—5:40 to 6:27 P.M.
Emptied 5/1/26—5:15 to 6:00 P.M.
Room Temp.—63°F.
Relative Humidity—26%
Wheat Temp.—60°F.
Moisture content—12%

Dosage
3053 Bu. Wheat @ 57lb per bu.
78lb Cyanogas used. 25.5lb per 100 bu.
2 pounds dropped at start.

Cage	No. Weevil Alive	Dead	Stupefied	Cage	No. Bran Bugs Alive	Dead	Stupefied
†1	0	10	0	1	0	13	0
2	0	10	0	2	0	9	0
3	0	10	0	3	0	3	0
4	0	10	0	4	0	23	0
5	0	10	0	5	0	20	0
6	0	10	0	6	0	13	0
7	0	10	0	7	0	17	0
8	0	10	0	8	0	11	0
9	0	10	0	9	0	17	0
*10	0	10	0	10	0	16	0
	0	100	0		0	142	0

† Check dropped ahead of wheat.
* Check dropped after run was completed.

Experiment No. 39 indicates that if the bin is already partly filled with wheat it is unnecessary to drop Cyanogas into the bin at the beginning of the run.

EXPERIMENT No. 39

General weather conditions	Filled 5/11/26—8 to 9 P.M.
High Temp.—62° F.	Emptied 5/14/26—5:30 to 7:30 P.M.
Low Temp.—49° F.	Room Temp.—65° F.
Mean Temp.—56° F.	Relative Humidity—39%
Precipitation—.02 inches	Wheat Temp.—54° F.
Relative Humidity	Moisture content—13.4%
7 A.M. Noon 7 P.M.	
96% 66% 46%	

Dosage: Cyanogas fed at rate of 25 pounds per 1000 bushels. Wheat started at 8 o'clock and allowed to run continuously for one hour at rate of 5000 bushels per hour. At end of first five minutes, Cyanogas feeder was started and checks No. 1 and No. 2 were dropped. Feeder stopped at end of 5 minutes and checks 1A and 2A were dropped. After ten minute interval feeder was again run for five minutes and checks No. 3 and No. 4 were dropped at the start and checks No. 3A and 4A at finish. Ten minute interval was again allowed and checks 4, 5, 4A and 5A were dropped in the same manner.

No. WEEVIL

Cage	Alive	Dead	Stupefied
1	0	10	0
1A	0	10	0
2	0	10	0
2A	0	10	0
3	0	9	1
3A	0	9	1
4	0	9	1
4A	0	10	0
5	0	10	0
5A	0	10	0
6	0	10	0
6A	0	10	0
	0	117	3

Various insects were used in determining the kill obtained in the large scale commercial experiments. Different species were not present in the same proportion. In a count of 400 weevils it was found that the two species were present in the following proportion: 99% *S. oryza* and 1% *S. granarius*. Out of 1000 "bran bugs", the different species were present in the following proportions:

T. confusum—50%
T. ferrugineum—40%
R. dominica—7.8%
C. pusillus—1.8%
S. surinamensis—0.4%

Effect of Fumigation on the Grain

CHEMICAL ANALYSIS: Chemical analyses were made to determine the residual hydrocyanic acid present in the wheat at the close of the fumigation. Analyses were made of wheat fumigated with different dosages of Cyanogas for different lengths of exposure and from different parts of the bin. Samples were also taken to the laboratory in tightly closed fruit jars. Fumigated wheat was milled within 24 to 48 hours after the fumigation and the residual hydrocyanic acid was determined within the next 24 hours in the various milled products.

The method of analysis used for the determination of the residual hydrocyanic acid was a modified Liebig method. The hydrocyanic acid was driven over from the tartaric acid solution, collected in a 1% solution of sodium hydroxide and titrated with a N/50 silver nitrate solution. Potassium iodide was used as an indicator. Two-ounce samples of whole wheat, screenings, or bran were placed in the distilling flasks with one liter of tartaric acid solution and 200 cc. of the distillate was collected in the sodium hydroxide solution. 400-gram samples of shorts and 800-gram samples of flour were placed in one-gallon earthen jars in the evening of the same day as milled. Two liters of water were added to each jar. The material was thoroughly mixed and allowed to settle until the following morning. One liter portions were decanted, filtered acidified with tartaric acid and distilled over as described above. The results of the analyses are given in Tables VII and VIII.

TABLE VII

Results of Analyses for Residual Hydrocyanic Acid

Expt. No.	Exposure in Days	Cyanogas Lbs. per 1000 bu.	HCN Parts Per Million: Wheat	Screenings	Bran	Shorts	Flour
					SACKED SAMPLES		
37	1	24.2	10.4	16.1	13.3	2.87	0.94
38	2	23.9	26.6	33.3	18.1	4.59	2.02
27	3	25.4	29.7	35.2	18.0	3.64	1.28
28	3	26.9	34.2	33.0	18.0	4.50	1.17
36	4	25.8	23.8	30.4	15.3	4.05	1.35
30	7	26.3	28.5	47.6	15.2	6.21	1.41
34	7	27.2	28.5	25.7	10.9	2.70	1.48
					JAR SAMPLES		
37	1	24.2	38.09	38.09	14.28	4.05	1.21
38	2	23.9	46.6	64.7	21.40	5.67	1.62
25	3	21.8	76.1	68.4	52.4	9.52	2.24
27	3	25.4	56.6	84.3	30.4	6.48	1.89
28	3	26.9	67.2	58.0	37.1	7.02	2.43
33	4	27.8	68.5	83.8	37.1	7.83	2.16
30	7	26.3	41.9	46.6	29.5	7.02	1.43
34	7	27.2	80.0	69.5	28.5	7.02	1.48

TABLE VIII

Residual HCN in Wheat from Various Parts of the Bin.

Expt. No.	Exp. Days	Cyanogas Lbs. per 1000 bu.	Bu. Wheat Fumigated	Residual HCN in Wheat Parts Per Million			
				Bottom	Top	Center	Average
1	1	20.0	9,000	15.8	16.8	29.1	20.5
3	1	20.7	10,400	17.8	22.7	24.7	21.7
5	1	21.1	3,500	16.6	13.8	41.4	23.9
6	1	27.1	3,500	32.6	30.7	27.7	30.3
18	1	27.7	2,700	30.6	34.5	39.5	34.8
*13	1	43.7	8,000	49.3	153.9	89.0	97.4
2	2	17.5	6,000	19.5	21.7	18.7	19.9
16	2	19.8	3,824	23.7	27.7	25.7	25.7
17	2	24.0	3,124	21.2	20.7	28.6	23.5
15	2	24.1	5,380	28.6	29.7	32.6	30.3
19	2	24.7	2,832	16.8	30.6	26.6	24.6
4	2	26.0	10,600	18.8	27.7	27.7	24.7
24	3	20.2	3,016	22.7	39.5	33.5	31.9
25	3	21.8	3,800	20.7	54.4	35.6	36.9
21	4	18.1	2,841	32.5	21.7	31.6	31.9
20	4	21.3	2,815	21.7	47.4	44.2	41.3
22	4	21.6	2,675	14.8	30.6	35.5	26.9

* Samples for No. 13 retained in sealed jars until analysis; all other samples retained in sacks.

A review of the tabulated results indicates that the amount of residual hydrocyanic acid present in the wheat would not be detrimental. The amount of residual hydrocyanic acid in the whole wheat fumigated in the recommended manner is less than that tolerated in almond paste. The Service and Regulatory Announcements of the United States Department of Agriculture* permit 5% of bitter almonds where there is a possibility of the almonds being used in the raw state, for edible purposes. Bitter almonds contain 0.12 to 0.18% of hydrocyanic acid. On this basis the recognized tolerance of hydrocyanic acid in bitter almonds used for food purposes would be 0.006 to 0.009% hydrocyanic acid, which is equivalent to 60 to 90 parts of hydrocyanic acid per million. The maximum residual hydrocyanic acid possible is shown in Table VII in the jar samples. The wheat taken at the close of the fumigation was placed in tightly closed fruit jars, so that there would be no loss of hydrocyanic acid in carrying the samples to the laboratory. Immediately upon reaching the laboratory these samples were screened and then tempered by adding water to the sample. This method of tempering would prevent any loss of hydrocyanic acid gas, in the jar samples. The wheat and the screenings were analyzed within 24 hours of the close of the fumigation. The wheat in these jar samples was mixed within the first 24 hours

*U. S. Dept. of Agric., Bureau of Chemistry. Service and Regulatory Announcements, Nov. 1914.

and the milled products were again sealed in the jars until analyzed. A comparison of the analyses of the jar samples with the sack samples clearly shows that, on exposure to the air, the wheat and the various milled products lose a considerable quantity of their residual hydrocyanic acid. One experiment was run with a high dosage of 45 pounds per thousand bushels to determine how quickly the residual hydrocyanic acid escaped. The wheat in this experiment analyzed 68.6 parts per million at the close of the 24 hour fumigation. The wheat was kept for a month in a sack and at the end of that period analyzed 28.6 parts per million. The bran made from this wheat analyzed 41.9 parts per million and a month later 22.7 parts per million. The shorts analyzed 8.9 parts per million and a month later 4.6 parts per million.

Wheat is sometimes washed before it is milled. Analyses were made of both unwashed and washed wheat and of the milled products of washed and unwashed wheat. Unwashed wheat, which showed 19 parts per million of residual hydrocyanic acid had only 2.02 parts per million after washing. Another sample which showed 68.5 parts per million before washing had only 11.4 parts after being washed. In this sample the bran from unwashed wheat analyzed 37.1 parts per million and from the washed wheat 3.8 parts per million. The shorts from the unwashed wheat contained 7.83 parts per million, while from the washed wheat, 3.2 parts per million. Flour from the unwashed wheat contained 2.16 parts per million, and from the washed wheat 0.41 parts per million.

The above chemical analyses indicate that the amount of residual hydrocyanic acid is small and most of this hydrocyanic acid would be lost as the wheat passes to the milling centers and goes through the milling processes.

FEEDING EXPERIMENTS: Although the chemical analyses indicated that there was not a dangerous quantity of residual hydrocyanic acid in the wheat following fumigation, it was decided to check this point by definite feeding experiments.

On February 7th, a flock of chickens consisting of eleven hens and one rooster was secured for the feeding experiments. From that day their only grain food consisted of fumigated wheat or wheat products, until the close of the experiment on May 20th. No injurious effects could be noted. During that period the residual hydrocyanic acid in their grain food was as follows:

Dates of Test, 1926	Whole Wheat	Bran	Sweepings
	Analyses of Feed Chickens Received		
Feb. 7 to Feb. 24	60 ppm.	27 ppm.	
Feb. 24 to March 24	23.5 ppm.	10 ppm.	
March 24 to April 12			140 ppm.
April 12 to May 3	85 ppm.		
May 3 to May 20			217 ppm.

ppm.=parts per million residual hydrocyanic acid.

A second flock of chickens consisting of six hens and one rooster were fed with fumigated grain from May 1st to May 12th. For a period of 5 days their food consisted of wheat containing 63.5 parts per million, bran containing 20.8 parts per million, and shorts containing 6.5 parts per million of hydrocyanic acid. For the remaining days they were fed upon the sweepings taken from the bottom of the bin which analyzed 217 parts per million of residual hydrocyanic acid. In addition to the grain and sweepings, bran containing 36.1 parts per million and shorts containing 20 parts per million were placed in the run so that they could feed upon it at will. No injurious effects could be noted from this diet which contained a fairly high percentage of residual hydrocyanic acid.

A flock of little chicks was fed on bran and shorts milled from fumigated wheat. Four of these chicks were 12 days old at the start of the experiment, while five were day-old chicks. They received this fumigated material plus table scraps as their first food. The experiment started on May 1st and was completed on May 12th. During this period of time they were fed on bran containing from 20 to 36 parts per million of residual hydrocyanic acid, and shorts containing from 6 to 20 parts per million of residual hydrocyanic acid. No deleterious effects could be noted from this diet.

A calf, nine weeks old, was procured and fed on a diet of fumigated corn, bran, and shorts for a period of nine days. Analysis showed the corn to contain 13.3 parts per million, the bran to contain 36.1 parts per million, and the shorts to contain 20 parts per million. No injurious effects could be noted in this experiment.

A shoat, weighing 120 pounds, was put on a diet of corn, bran, and shorts for a period of five days. During this period the shoat was permitted to feed at will upon the fumigated products. The corn used in this experiment showed a hydrocyanic acid content of 39 parts per million; the bran, 16.3 parts per million; and the shorts, 2.6 parts per million. No deleterious effects were noted and the hog increased 12 pounds in weight.

From the evidence obtained from the feeding experiments and the chemical analyses it is perfectly apparent that the residual hydrocyanic acid in fumigated grain and milled products is not present in sufficiently large quantities to cause any deleterious effects when eaten.

EFFECT ON THE QUALITY AND BAKING PROPERTIES OF THE FLOUR: Although preliminary tests on the small scale experiments indicated that there would be no change in the quality of the flour milled from fumigated wheat and that such flour would produce just as good bread as flour from untreated wheat, a series of tests were run using samples taken from different commercial experiments. These samples were so selected as to represent fumigations running from one to seven days. The samples were milled and baking tests were run by the Southwestern Laboratories, Kansas City, Missouri. The Southwestern Laboratories are the official laboratories for making such tests for the Board of Trade of Kansas City, Missouri. The samples were turned over to the Laboratories with the instruction to examine the treated and the untreated material and to render a signed report on any peculiarities such as odor, differences in protein content, or baking qualities which might be noted. Tabulated results of a representative series of these baking and protein tests are given in Table IX.

An examination of these data indicates that there is no striking difference in the percentage of protein obtained. The percentage of ash which serves as an index of the quality of the flour showed no striking difference. In the baking tests, no differences could be noted. It was also reported that there was no objectionable odor in the wheat and that no odor was detected in the flour.

EFFECT ON THE GERMINATION OF THE WHEAT: Although the wheat which was the subject of our experiments was not destined to be used as seed wheat, it was thought advisable to make determinations of the effects of the fumigation on the germination. Some of the samples of wheat used were several years old and actually represented what might be termed "dead wheat". The method of making these tests consisted in placing 100 kernels of both the fumigated and the unfumigated wheat in an incubator between layers of moist blotting paper. The germination tests were started from one week to six weeks after the close of the fumigation. The counts were made after five days of incubation. The results of the

TABLE IX

Baking and Protein Tests—Commercial Experiments

			Protein %				Ash % Flour		Baking %							
		Cyanogas	Wheat		Flour				Absorption of Water		Volume of Loaf		Color of Loaf		Texture of Loaf	
Expt. No.	Exp. Days	Lbs. per 1000 bu.	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check	Treated	Check
37	1	24.2	12.09	11.93	9.70	9.74	0.47	0.46	61.0	60.0	100	100	100	100	100	100
38	2	23.9	12.33	12.25	10.05	10.09	0.48	0.48	60.0	60.0	100	100	100	100	100	100
27	3	25.4	14.92	14.80	12.77	12.79	0.49	0.47	62.5	62.5	100	100	100	100	100	100
25	3	21.8	11.29	11.21	9.34	9.26	0.51	0.53	60.0	58.0	100	100	100	100	100	100
28	3	26.9	14.16	14.01	12.01	12.09	0.49	0.49	62.5	62.5	100	100	100	100	100	100
36	4	25.8	14.68	14.76	12.33	12.31	0.43	0.46	61.0	60.0	100	100	100	100	100	100
33	4	27.8	14.01	14.05	11.79	11.65	0.47	0.45	60.0	60.0	100	100	100	100	100	100
30	7	26.3	14.10	14.05	11.75	11.65	0.49	0.45	60.0	60.0	100	100	100	100	100	100
34	7	27.2	13.17	13.29	10.77	10.85	0.49	0.46	60.0	60.0	100	100	100	100	100	100

TABLE X

Germination Tests.

Expt. No.	Days Exposure	Cyanogas Lbs. per 1000 bu.	Percent Germination	
			Treated	Check
117	1	19.9	1	0
118	1	19.9	1	0
123	1	22.1	0	1
111	1	26.5	1	0
112	1	26.5	1	0
113	1	26.5	4	0
120	1	27.7	88	75
121	1	27.7	90	65
6	1	27.1	3	1
18	1	27.7	2	0
9	1	30.9	23	23
19	2	24.7	3	5
27	3	25.4	89	81
23	3	26.9	90	71
21	4	18.1	53	52
36	4	25.8	95	90
33	4	27.8	63	69
30	7	26.3	65	61
34	7	27.2	24	33

germination tests are recorded in Table X. No particular effect on the germination was noted in the fumigated wheat. These results confirmed the work of other investigators who have found that fumigation with hydrocyanic acid gas has no influence on the germination, providing the grain is dry at the time it is fumigated and has been sufficiently aerated after the fumigation (5).

EFFECT ON THE APPEARANCE OF CORN: In the fumigation of corn, it was noted that yellow corn showed certain dull areas on the kernel and that the white corn exhibited certain yellow spots at the close of the fumigation. In the case of the yellow corn, this slightly altered appearance would probably not be objectionable. The yellow spots on the white corn were due to a staining of the epidermis. When the epidermis was removed it was found that the stain did not extend deeper into the kernel. These yellow spots gradually fade on exposure to the air.

RECOMMENDATIONS

1. Dosage

    25 pounds of Cyanogas G-Fumigant per 1000 bushels of wheat. When starting with empty bin 2 pounds of Cyanogas should be dropped before grain is started. This is not necessary when the bin is partly filled.

2. Exposure

    72 hours.

3. Application

    Cyanogas G-Fumigant is applied by means of a special roll feed hopper that will feed an even stream. The feed should run as follows as determined by the rate at which the wheat is running off the belt:

Rate of Wheat Flow per Hour	Cyanogas per Minute
4000 bushels	26.5 ounces
5000 "	33.3 "
6000 "	40 "

Any of these rates is equivalent to a dosage of 25 pounds of Cyanogas per 1000 bushels. Once the hopper is adjusted to feed the required dosage, this adjustment should remain constant and fumigations continued with only an occasional check.

4. Precautions
    1. Stand on windward side when filling the hopper.
    2. Ventilation:
        a. See that air is allowed to circulate:
            x. above the bins
            y. in tunnel rooms
        b. Cross ventilation should be provided near the "boot"
    3. When it is necessary to clean out bin, allow air to circulate through it for fifteen minutes before entering.
5. Special precautions when no outside vent is used
    1. Do not allow workmen to remain close to bin when filling.
        a. Machinery may be oiled or observations made providing the operator does not remain near the opening for any long period of time.
    2. The machinery should be moved and the manhole closed as soon as the run is completed.

CONCLUSIONS

The experiments given in this paper demonstrate the practicability of controlling grain insects in storage bins by fumigation with Cyanogas Calcium Cyanide. It would appear that insects infesting grain in railroad cars could be fumigated in a similar manner, applying the Cyanogas at the time the car is loaded. It would also appear that a smaller country elevator could be fumigated in a similar manner. There is also the problem of fumigation of grain stored in sacks. The solution of these problems is left to the future.

SUMMARY

1. It has been demonstrated that it is possible to fumigate a large bin of wheat by feeding Cyanogas Calcium Cyanide G-Fumigant into the bin with the wheat at the time it is being filled.

2. A special machine has been designed to deliver the fumigant.

3. All fire risk is removed by the use of Cyanogas since it is non-inflammable and non-explosive under ordinary conditions.

4. Cyanogas will give a commercial control of the common beetles found in stored grain.

5. Fumigation with Cyanogas Calcium Cyanide destroys the immature stages of the insects as well as the adults.

6. Fumigations may be conducted with a temperature as low as 40° F.

7. Treated wheat may be stored without danger of shrinkage, dockage, or heating due to insect activity.

8. Wheat fumigated with Cyanogas Calcium Cyanide has no objectionable odor.

9. Chemical analyses and feeding experiments have demonstrated that there is no danger from residual hydrocyanic acid.

10. Fumigation of wheat with Cyanogas Calcium Cyanide does not alter the quality or the baking properties of the flour which may be milled from it.

11. Fumigation does not effect the germination of the wheat.

LITERATURE CITED

(1) Back, E.A. and Cotton, R.T. Stored-Grain Insects, U.S. Dept. of Agr. Farm. Bul. 1260, July, 1922, pp. 43-44.

(2) Back, E.A. and Cotton, R.T. Effect of Fumigation upon Heating of Grain Caused by Insects, Jl. of Agr. Research, Vol. XXVIII, No. 11, June 14, 1924, pp. 1103-1116.

(3) Back, E.A. and Cotton, R.T. Control of Insect Pests in Stored Grain, U. S. Dept. of Agr. Farm. Bul. 1483, June, 1926, p. 25.

(4) Dean, Geo. A. and Swanson, C. O. Effect of Common Mill Fumigants on the Baking Qualities of Wheat Flour, Kans. State Agri. Expt. Sta. Bull. 178, May, 1911.

(5) Maryland Agr. Expt. Station. The Effect of Hydrocyanic Acid Gas Upon Grains and Other Seeds, Bul. No. 75, June, 1901.

(6) Neifert, Ira E., Cook, F. C., Roark, R. C., and Tonkin W. H. Fumigation Against Grain Weevils With Various Volatile Organic Compoands, U. S. Dept. of Agr. Dept. Bul. 1313, Jan., 1925.

How Fumigation Affects Wheat

By DR. C. O. SWANSON and E. B. WORKING
Department of Milling Industry, Kansas State Agricultural College

An effective, safe and convenient fumigant for grain is highly desired. Carbon bisulphide is ruled out because of the fire hazard. Some fumigants are too slow; some have other properties which make their use for grain impracticable.

The investigations reported in this paper were for the purpose of determining what effects calcium cyanide used as a fumigant, has on wheat and mill products. We did not test the effectiveness of insect killing. These experiments were conducted in co-operation with the American Cyanamid Sales Company, 511 Fifth avenue, New York. The company representatives for this experiment were: Dr. William Moore, Director of Research, and Mr. Gilbert Schenck, Entomologist. Mr. Schenck was present during the entire period these investigations were in progress.

When calcium cyanide is exposed to the air it slowly gives off hydrocyanic acid in the form of a gas. This acid is one of the most effective insecticides known. As the acid is a violent poison, it is first necessary to know if the treatment of wheat with calcium cyanide leaves any residue in mill products in large enough quantities to be harmful to animal life. It is also necessary to know if treatment of wheat with calcium cyanide has any injurious effect on the milling or baking qualities.

The American Cyanamid Sales Company recommend using 25 pounds of their calcium cyanide for each 1,000 bushels of wheat. The chemical is in a fine granular form like medium fine sand. In fumigating grain it is mixed with the stream by means of a special feeder when the grain is transferred from one bin to another. After treatment the grain is allowed to stay in the bin for three days or more.

Twenty-five pounds of the calcium cyanide for 1,000 bushels of wheat means one part of the chemical for 2,400 parts of the grain; hence in calculating the quantities used in these tests one gram calcium cyanide for 2,400 grams wheat represent the recommended dosage. This is equivalent to 113 parts per million hydrocyanic acid estimating that the calcium cyanide used was equivalent to 49% pure sodium cyanide. The general plan of the experiment was to treat portions of wheat, 2,400 grams each, with 1, 2 and 3 grams of calcium cyanide so as to have single, double and triple dosages. The wheat was put in tin pails having covers fitting like those of baking powder cans and calcium cyanide in carefully weighed portions added after which the whole was thoroughly mixed by rotating the pail. The covers were pressed tight and the pails allowed to stand for one, three, five, and seven days respectively. While fitting fairly tight, the covers did not make the pails air tight. At the end of each treating period, samples of wheat were removed for the hydrocyanic acid determinations. The bulk of each sample was scoured, tempered, and milled and the scoured wheat and milled products were analyzed for hydrocyanic acid, one determination being made soon after treatment and another after a definite period of exposure. Then the flour was baked, the bread scoured for quality and the bread analyzed for hydrocyanic acid.

Residual Hydrocyanic Acid in Wheat and Milled Products

All the treated samples were treated for germination by the seed laboratory of Kansas State Agricultural College. Only two samples showed a lower germination test than the untreated samples. One of these had been treated with a single dose and exposed to the action of calcium cyanide for one day. The other sample had been treated with triple dose and exposed for seven days. All the other samples showed a higher germination test than the check samples. It seems that the treatment with calcium cyanide had had a stimulating effect on all but two samples.

Analysis for hydrocyanic acid was made by placing the material in a large round bottom Pyrex flask, adding 800 cc of water, acidifying with tartaric acid and then distilling about 200 cc into a one per cent solution of sodium hydroxide. The amount of hydrocyanic acid was estimated by titrating with a N/50 solution of silver nitrate using potassium iodide as indicator. The results are expressed as parts per million.

The samples were milled by Mr. C. W. Oakes on an Allis experimental mill and 2,000 grams were used for each milling test. There was no indication in the milling results to show that the milling qualities had in any way been affected by the treatment.

The amount of residual hydrocyanic acid found in wheat and milled products are given in Tables I-IV. The samples of wheat were treated with single, double and triple doses of calcium cyanide or at the rate of 25, 50 and 75 pounds of calcium cyanide per 1,000 bushels of grain. Table I gives the results when wheat was treated for one day with calcium cyanide. Table II, the results when the treatment was for three days. Table III and IV, when the treatment was for five and seven days respectively. Single dose or one part of the calcium cyanide for 2,400 parts wheat means 113 parts of hydrocyanic acid per million, double dose 226 parts and triple dose 339 parts respectively. The end of the treatment was the time when the wheat was removed from the pail to be prepared for milling.

Hydrocyanic acid is lost rapidly from the wheat during treatment. Wheat treated with single, or recommended dose, lost the first 24 hours 37 per cent of what was added, 62 per cent in 3 and 5 days, and 73 per cent in seven days. The amount of residual acid left in the wheat and milled products was proportional to the amount added. Thus the residual amount for double dose treatment was approximately twice that found for the single dose, and for the triple dose it was approximately three times the amount left when the single dose was used. This statement holds as a general rule for the wheat and all the milled products, although there is some variation among the figures.

About half the amount present at the end of the treating period was lost when the wheat was exposed to the air for 24 hours after removing from the treated can. This was true both of the unscoured and the scoured wheat. Scouring removes some of the hydrocyanic acid but very much more is lost on exposure for 24 hours than by scouring. The scourings contain more residual hydrocyanic acid than any of the milled products.

Wheat did not lose as much hydrocyanic acid while it was being tempered for 24 hours as when it was exposed dry for the same length of time. Wetting the wheat in tempering retards the rate at which the hydrocyanic acid escapes.

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Bran from wheat treated with single dose of calcium cyanide contained immediately after milling more hydrocyanic acid than the wheat. When double and triple doses were used, the bran contained less than the wheat. Bran like wheat lost considerable hydrocyanic acid on exposure to the air for 24 hours. Shorts contained from one-sixth to one-half as much hydrocyanic acid as the bran, and it lost on exposure for 24 hours one-half to two-thirds of that present immediately after milling.

Effect of Exposing Treated Wheat Before Milling

Flour contained less hydrocyanic acid than any other of the milled products and on exposure to the air for six days it lost from two-thirds to four-fifths of that present immediately after milling. After the five and seven days treatment, single dose, no hydrocyanic acid was found in the flour.

In no case was any hydrocyanic acid found in the baked bread.

In actual practice wheat treated with calcium cyanide would not be milled immediately after treatment. Wheat was treated with the recommended or single dose for three days. Then the wheat was exposed to the air for 24 hours before it was prepared for milling. The results are given in table V. These figures confirm the results on exposure presented in Tables I-IV.

TABLE I

RESIDUAL HYDROCYANIC ACID IN WHEAT AND PRODUCTS

One day treatment.

Description of Sample	Hydrocyanic Acid in Parts Per Million Single Dose	Double Dose	Triple Dose
Amount originally added to the wheat	113.0	226.0	339.0
Wheat immediately after treatment	71.3	138.2	207.4
Wheat exposed 24 hours to air after treatment	23.8	49.7	75.6
Wheat scoured after treatment	64.8	129.6	192.2
Wheat scoured and exposed 24 hours	25.9	49.7	71.3
Wheat after tempering 24 hours	36.7	79.9	129.6
Scourings	448.1	1378.4	2240.5
Bran immediately after milling	84.2	86.4	101.5
Bran after exposure 24 hours	43.2	60.5	79.9
Shorts immediately after milling	6.5	13.0	19.4
Shorts after exposure 24 hours	2.2	4.3	10.8
Flour immediately after milling	1.1	2.2	3.2
Flour after exposure 6 days	0.3	0.5	0.8
Bread	0.0	0.0	0.0

TABLE II

RESIDUAL HYDROCYANIC ACID IN WHEAT AND PRODUCTS

Three days treatment.

Description of Sample	Hydrocyanic Acid in Parts Per Million Single Dose	Double Dose	Triple Dose
Amount originally added to wheat	113.0	226.0	339.0
Wheat immediately after treatment	48.2	106.8	112.3
Wheat exposed 24 hours to air after treatment	21.6	41.0	47.5
Wheat scoured after treatment	41.0	99.4	155.5
Wheat scoured and exposed 24 hours	17.3	32.4	49.7
Wheat after tempering 24 hours	25.9	71.3	82.1
Scourings		432.0	583.2
Bran just after milling	54.0	64.8	82.1
Bran after 24 hours exposure	30.2	54.0	60.5
Shorts immediately after milling	15.1	23.8	36.7
Shorts after 24 hours exposure	4.3	13.0	15.1
Flour immediately after milling	1.6	3.2	4.3
Flour after 6 days exposure	0.0	0.8	0.0
Bread	0.0	0.0	0.0

Disappearance of Hydrocyanic Acid

It was desired to know at what rate the hydrocyanic acid disappeared from wheat when very large amounts were added. Hence 20 times the normal dose were added to 2 samples and also 40 times the normal dose to another 2 samples of wheat. These samples were then kept in the pails for 10 days. Two samples treated with 20 times normal dose and two samples from 40 times normal dose were analyzed for hydrocyanic acid immediately after treatment. Duplicate samples from both dosages were exposed to the air for 24, 48 and 72 hours respectively. The results of the analyses are given in Table VI. During the 10 days treatment about 65 to 80 per cent of the hydrocyanic acid added to the wheat disappeared and during the first 24 hours exposure, about 2-3 of the remainder disappeared. At this time the amount of residual hydrocyanic acid was the same for both the 20 and 40 times normal dose. During each succeeding 24 hours half disappeared of what was present at the time of the previous analysis. At the end of 72 hours no more was present than what was found in wheat after one day's treatment single dose. (See Table VI and compare with Table I).

Baking Tests of Treated Wheat

The results of the baking tests are presented in Table VII. These tests were made by the use of the high speed mixer developed in the Department of Milling Industry, Kansas State Agricultural College. This test gives the flour a severe treatment and if any weakness exists, it will be shown in the lessened loaf volume and in poor texture. The figures show that the baking qualities were not in any way injured by the treatment with the recommended dose of calcium cyanide. No marked influence could be noticed with the double dose. There was a slight decrease in loaf volume with the triple dose when the flour was baked at once. When this flour had stood for six days the volume was, within experimental error, the same as the volume obtained on the check sample. The treatment with the recommended dosage showed in most cases a slight improvement over

TABLE III

RESIDUAL HYDROCYANIC ACID IN WHEAT AND PRODUCTS

Five days treatment.

Description of Sample	Hydrocyanic Acid in Parts Per Million Single Dose	Double Dose	Triple Dose
Amount originally added to wheat	113.0	226.0	339.0
Wheat immediately after treatment	41.0	79.9	108.0
Wheat exposed 24 hours to air after treatment	17.3	43.2	60.5
Wheat scoured after treatment	36.7	75.6	108.0
Wheat scoured and exposed 24 hours	15.1	34.6	43.2
Wheat after tempering 24 hours	23.8	69.1	79.9
Scourings	466.6	757.6	1162.0
Bran immediately after milling	38.9	62.6	69.1
Bran after 24 hours exposure	34.6	47.5	60.5
Shorts immediately after milling	17.3	23.8	30.2
Shorts after 24 hours exposure	6.5	8.6	17.3
Flour immediately after milling	0.5	1.62	2.7
Flour after 6 days exposure	0.0	0.6	0.5
Bread	0.0	0.0	0.0

TABLE IV

RESIDUAL HYDROCYANIC ACID IN WHEAT AND PRODUCTS

Seven days treatment.

Description of Sample	Hydrocyanic Acid in Parts Per Million Single Dose	Double Dose	Triple Dose
Amount originally added to wheat	113.0	226.0	339.0
Wheat immediately after treatment	30.2	67.0	97.2
Wheat exposed 24 hours to air after treatment	15.1	34.6	51.8
Wheat scoured after treatment	23.8	47.5	97.2
Wheat scoured and exposed 24 hours	19.4	36.7	54.0
Wheat after tempering 24 hours	17.3	38.9	62.6
Scourings	247.7	382.3	937.0
Bran immediately after milling	41.0	64.8	82.1
Bran after 24 hours exposure	36.7	47.5	56.2
Shorts immediately after milling	6.5	10.8	13.0
Shorts after 24 hours exposure	2.2	4.3	6.5
Flour immediately after milling	0.8	1.1	1.6
Flour after 6 days exposure	0.0	0.3	0.3
Bread	0.0	0.0	0.0

TABLE V

EFFECT OF EXPOSING THE TREATED WHEAT TO AID BEFORE MILLING

Description of Sample	Hydrocyanic Acid in Parts Per Million Sample A	Sample B
Wheat exposed 24 hours	36.7	32.4
Wheat exposed 24 hours and scoured	30.2	....
Wheat exposed 24 hours and then tempered 24 hours	19.4	17.3
Bran immediately after milling	41.0	38.9
Bran exposed to air 24 hours after milling	36.7	38.9
Shorts immediately after milling	19.8	9.7
Shorts exposed to air 24 hours after milling	2.2	2.2
Flour immediately after milling	1.1	0.8
Bread	0.0	0.0

TABLE VI

RESIDUAL HYDROCYANIC ACID IN WHEAT TREATED WITH LARGE DOSAGES OF CALCIUM CYANIDE

Ten days treatment.

Description of Sample	Hydrocyanic Acid in Parts Per Million 20 x Normal Dose A.	20 x Normal Dose B.	40 x Normal Dose A.	40 x Normal Dose B.
Amount originally added to wheat	2260	2260	4320	4320
Wheat immediately after treatment	786	769	832	866
Wheat exposed to air 24 hours	283	264	272	268
Wheat exposed to air 48 hours	127	123	125	127
Wheat exposed to air 72 hours	66	58	61	56

the check samples. All the flour samples were given the maturing treatment with chlorine using the apparatus of the Industrial Appliance Company, Chicago.

Feeding Experiments.

Two lots of baby chicks, 17 in each lot, were used in the feeding experiments. The check lot was fed fresh buttermilk at all times and ground untreated wheat spread on a board three times a day for five days, after that the ground wheat was put in self feeders for four days. The other lot was fed the same as the check lot except that the wheat was treated for two days with double doses of calcium cyanide. This wheat before grinding contained 84.2 parts per million hydrocyanic acid, and after grinding 23.8 parts per million. One chick in the check lot died on the 4th day of the experiment, and one chick in the lot fed treated wheat died on the third day. There was no evidence that this was due to feeding treated wheat. At the close of the feeding period the chicks were observed by Professor L. F. Payne, Professor of Poultry Husbandry, and Dr. J. S. Hughes, Professor of Chemistry and Expert in Nutrition, Kansas State Agricultural College. Both men pronounced the chicks normal in every way.

One mature hen, as a check, was fed untreated whole wheat, also bran and shorts from untreated wheat made into a mash with water, and some buttermilk. The other mature hens were fed the same ration except that the wheat was treated two days with calcium cyanide, double dose, and contained at the beginning 84.2 parts per million of hydrocyanic acid. After five days, wheat containing 820 parts per million was fed, but no bran or shorts. No ill effects could be noticed on these hens. Both continued to lay eggs during the experiment. The feeding of both the baby chicks and hens was done by Mr. Ben Grosse.

Mr. E. L. Griffin and Mr. I. E. Neifert of the United States Department of Agriculture have made determinations on the absorption and retention of hydrocyanic acid when wheat, flour, fruits and vegetables are fumigated with this gas. They found no trace of hydrocyanic acid in flour seven days after fumigation. Wheat contained from 1.2 to 1.2 parts per million 90 days after fumigation. Fruits and vegetables contained much larger amounts of hydrocyanic acid, but more than one-half disappeared during one day's exposure. The report of their investigations are found in United States Department of Agriculture, Bulletin No. 1149.

Summary

The American Cyanamid Sales Company recommended using 25 pounds of their calcium cyanide for each 1,000 bushels of wheat; this to be mixed with the wheat by means of a special feeder when transferred from one bin to another. For the purpose of determining the amount of residual hydrocyanic acid left in wheat and milled products, calcium cyanide was mixed with wheat in this proportion, and also in double and triple doses. At the end of treating periods which were 1, 3, 5 and 7 days, the wheat was analyzed for hydrocyanic acid. Then it was milled and the milled products analyzed. Determinations were also made to ascertain the rate of disappearance from wheat and milled products. This was done by exposing wheat and products for definite periods of time. Baking tests were made on the flour from treated wheat. A feeding test was made with baby chicks and mature hens. The treated wheat was also tested for germination.

TABLE VII

BAKING TESTS OF FLOUR FROM WHEAT TREATED WITH CALCIUM CYANIDE

Days Treatment	Dosage	Loaf Volume CC	Texture Percent
0	0	2050	95
0	0	2090	96
0	0	2065	98
I	1	1990	96
I	2	2045	94
I	3	2020	96
III	1	2035	96
III	2	1920	94
III	3	1925	94
V	1	1970	96
V	2	2030	96
V	3	2000	94
VII	1	2050	96
VII	2	2030	96
VII	3	1950	94
III	1	2060	96 (1)
III	1	2110	96 (1)
III	1	2070	98 (2)
III	3	2040	96 (2)

(1) Wheat was exposed to air 24 hours before scoured and tempered

(2) Flour was exposed to air in cotton sacks

Wheat treated with the recommended dosages contained approximately 50 parts hydrocyanic acid per million, the bran a similar amount, the shorts about 15 parts per million, and the flour one part. The hydrocyanic acid disappears rapidly from wheat and milled products. Flour exposed in cloth sacks for six days contained only one-quarter part per million. This is only a faint trace and almost at the limit of the determination. The bread contained no hydrocyanic acid.

No injurious effects could be noticed on the milling qualities for all dosages nor on the baking qualities when the single or double recommended dosage was used. There was a slight decrease in loaf volume with the triple dose. However, when this sample had stood six days, the volume came back within experimental error of the volume obtained from the untreated wheat. The treatment with the recommended dosage showed in most cases a slight improvement over the check sample.

No injurious effects from treated wheat or products were obtained in the feeding experiments, nor was there any injury to the vitality as shown in the germination tests. There is nothing in the data obtained in these experiments which indicates that treating wheat with calcium cyanide for purpose of fumigation affects the wheat or the flour in any way different from that brought about by fumigation with liquid hydrocyanic acid. These milling and baking tests were made shortly after the treatment. In ordinary practice, the wheat would be milled after a much longer time. Hence the residual amount of hydrocyanic acid would be much less than shown by the data in these experiments. Consequently there is nothing which indicates that the small residue which is left in the wheat is in any way harmful.

PESTS OF THE APIARY

Cyanogas Calcium Cyanide has recently been found to occupy a very definite place among the requisites of the apiarist.

The use of hydrocyanic acid gas in the neighborhood of a product such as honey which is to be consumed as food has naturally caused inquiry as to the safety of such a practice.

The research so ably conducted and reported on in the following paper by Mr. C. L. Corkins, State Entomologist of Wyoming, has proven beyond a doubt that Cyanogas is not only effective in fulfilling its special uses for the keekeeper but also that it may used without danger of injuring or impairing the flavor of the fumigated honey.

NEW CHEMICAL FOR BEEKEEPERS*

By C. L. Corkins
State Entomologist of Wyoming

Quick, Effective, and Convenient Way to Destroy Wax-moth Larvae, Bees, or Ants

Calcium cyanide is a new and most useful chemical for the beekeeper. In Wyoming we have used it for five different purposes during the past three seasons. Listed in the probable order of their importance to American beekeeping these purposes are: First, efficient destruction of diseased colonies as the first step in the burning treatment; second, fumigation for the control of the bee moth; third, destruction of wild bees in trees, rocks, and other places; fourth, killing of colonies in fall instead of wintering; fifth, control of ants in the apiary.

The active killing agent of calcium cyanide is the deadly gas, hydrocyanic acid gas, which is liberated upon exposure to the air. Since hydrocyanic acid gas is notable as a most deadly poison to all life, two questions immediately arise: first, is it safe to use? and second, will the honey and combs become contaminated and poisoned?

In answer to the first question, it may be said that calcium cyanide is now in general use as an insectiticide, both for indoor fumigation and outdoor destruction of certain insects. In the case of indoor fumigation it has largely displaced the old sodium cyanide and sulphuric acid method of generation of hydrocyanic acid gas, because it has taken away most of the elements of danger in such a practice. It is safer to use chiefly for two reasons. The liberation of the poison gas is slow and gives the operator time to place the charge and retire from the building. In addition to this, there is a warning odor with calcium cyanide that you do not get in the case of the liberation of pure hydrocyanic acid gas. The warning odor is due to the generation of a small amount of calcium carbide.

Used in the open air, there is positively no danger in handling calcium cyanide if

*Gleanings in Bee Culture; Vol. LIV, No. 10, pp. 644-646, Oct. 1926.

the ordinary precautions in the use of any poison are employed. The rapid air dilution of the slowly generated gas makes it perfectly safe to handle, especially if one heeds the warnings of the calcium carbide odor. Tons of this material are being used by the American farmers in the destruction of rodent and insect pests with no casualties noted to date.

Effect Upon Honey

The question of the poisoning of honey, either in the destruction of bees or the fumigation for the bee moths, and its subsequent use as either human or bee food is, of course, of the utmost importance. As one beekeeper put it, "I am sending you a sample of honey from a colony of bees killed by the cyanide process. Please eat it and let us know if it is all right for human food."

Although there seemed little likelihood of the honey being poisoned, we preferred to allow a rabbit to be the martyr to the cause. As a consequence, 50 cc. of the sample were fed directly to the stomach of a rabbit through a stomach tube, and the rabbit still lives, though that was a year ago.

It was then decided to carry on some extensive experiments to settle this question definitely. The honey tested was all placed in three-frame nuclei, and these in turn kept in an air-tight room during the fumigation process, thus giving an exaggerated effect over outdoor conditions. The dosages of the poison were also exaggerated, so that the least possibility of poisoning the honey would be detected. Amounts as high as five ounces of calcium cyanide to a three-frame hive were used.

Three different types of honey were given treatment: namely, sealed honey, open cells of honey, and extracted honey to which equal parts of water had been added. In the last instance, this thinned honey was placed in shallow containers so that the honey was ¼" in depth, thus giving a large surface exposure as compared to the depth, thus simulating a condition of open cells of green nectar in the hive.

Fumigation was carried on for 24 and 48 hour periods in the closed room at a temperature of 18° to 22° C. Some hives were given the usual ⅝-inch entrance open. Others were closed tight with wrapping paper. Some of the gas was liberated under normal-air humidity conditions. In other cases, moistened blotting paper was used in the hives to raise the relative humidity.

At the conclusion of fumigation, the honey was immediately cold extracted, diluted with equal parts of distilled water and placed in air-tight containers. In the majority of cases, 50 cc. of this material was fed to 24-hour-starved rabbits directly through a stomach tube. In no case was there the least discomfort displayed, and the university veterinarian pronounced them all normal.

A man weighing 160 pounds would have to eat a little over two pounds of honey at one sitting to have an amount proportionate to that given a rabbit of average size in the experiment.

Failing to get any reaction from the rabbits by the above methods, pure hydrocyanic acid gas was bubbled through honey diluted as above, and 50 cc. fed after exposure to the air for thirty minutes. This produced violent convulsions in the rabbit, but first-aid treatment prevented death. This was the particular rabbit that went through the original experiment, taking my place as the patient.

No Danger of Poisoning Honey

These results of the experiments, showing that there is no danger of poisoning honey in the ordinary fumigation with calcium cyanide, were much as expected. All of the salts of cyanide are unstable and quickly broken down in the presence of the weakest acid. If the cyanide were actually absorbed in the honey, it would doubtless mean the formation of some one or more of its salts. Such would be prevented by the acid reaction of all honeys. In the case of the experiment where the gas was passed through the honey, it doubtless would have been harmless if allowed to stand in a shallow dish in the open air for some time, or heated, as would be the case with foul honey before being used as a bee food.

It should also be further said that this method of fumigation is now a standard practice in restaurants and other places where food is exposed to the gas, and, even when little or no precaution is taken, the foods are found not to be harmful.

It would seem rather certain, then, that honey exposed to any of our practices of calcium cyanide fumigation can be safely used as either a human or a bee food. Our practical experience, as well as experimental data in Wyoming, supports such a statement.

Use in Destroying Diseased Colonies

Now for methods in the use of calcium cyanide by the beekeeper. Its use for the destruction of diseased colonies prior to burning seems to me to be of primary importance because in the destruction of a diseased colony by a novice there is many an opportunity to scatter infection. By the sulphur, formaldehyde, or other usual methods of killing the colony, there is every possibility in the

world for either nurse or field bees, engorged with diseased honey, to get out of the hive and wander into a healthy colony. Far more danger of spreading disease is apparent in the method of throwing the hive-bodies containing live bees onto a raging fire, even though this be done at night and the entrance first closed.

By the calcium cyanide method there is not the least danger of getting live bees into the air, if properly handled. Wherever possible, the bees should be killed at night when all are in and quiet. About a tablespoonful of "G" grade calcium cyanide granules are spread out on a cardboard, and slipped into the entrance of the hive. The entrance is then closed. In five minutes, or less, the bees are all dead and the hive may be thrown onto the fire. In doing this, great care should be exercised not to lose any of the dead bees out of the hive, as disgorged droplets of diseased honey may be left on the tongues of the dead bees and these might be picked up by healthy bees during the robbing season.

Some commercial beekeepers with many out-yards at considerable distances can not afford to go back to the yard at night just to kill a few colonies. In this event the bees may be killed during the day at the normal time of visitation of the yard for manipulation purposes. However, one should cyanide the diseased colonies immediately upon arrival at the yard. Give a double dosage and leave the entrance open. Then, during the course of the hour or more that may be required for other work in the yard, the nurse bees that may have been out on "play flights" will have entered the colony and have been killed. Theoretically the field bees which may return later are sterile and will do no harm if they enter healthy colonies. After the killing operation, any dead bees found around the outside of the hive should be covered up with dirt.

In the case of killing healthy bees, the method is naturally the same, except that the ordinary precautions against outside bees need not be taken.

Use in Fumigating Combs

Fumigation of combs to kill the bee-moth may be done by stacking the hives, if they are fairly air-tight, and placing the dosage at the bottom of the stack, or by stacking the supers crisscross in a tight building, and sprinkling the calcium cyanide out finely on newspapers placed here and there about the building. In either event, the operator should leave the building as soon as possible and *lock all doors and windows.* After a twenty-four-hour treatment, open the building sufficiently to give a draft and *do not enter for two or three hours.*

For stacked-super fumigation, use at the rate of four pounds to 1000 cubic feet of space. Half as much will suffice for tight-house fumigation. These dosages will kill bee-moths in all stages.

For the destruction of wild bees in houses, trees, rocks, and other cavities, a small hand dust-gun to force the dust in under pressure is used. Each of the inspectors in Wyoming is equipped with such a dust-gun, and wherever wild bees are discovered they are killed, and, if possible, the entrances closed. A hundred and thirty wild swarms were thus treated in one county last season. This will help to reduce the menace of wild bees in the distribution of disease. However, this situation can not be entirely handled by inspectors. The method is here discussed in the hope that it will enlist beekeepers to use it in co-operation with the inspectors to eliminate as many wild bees as possible. In the intermountain region, at least, these bees are a serious factor in the control of American foul brood.

Use in Destroying Ants

This same calcium cyanide is perhaps the most satisfactory chemical used for the control of ants in the apiary. Out-yards are most often bothered with mound-building ants. To kill these, open up the mounds with a spade, throw in two or three tablespoonfuls of the cyanide, and throw the mound contents back over it. In a few cases the treatment may have to be repeated. Do not use this close to the entrance of a beehive or bees will be killed. In the case of the burrowing ants with small colonies, this treatment is not so satisfactory. However, with due diligence, their homes may all be found and cleared out by the same treatment as with the mound-building ants.

Calcium cyanide is now readily obtainable on the commercial markets. The "G" grade granules are satisfactory for all uses to which the beekeeper may wish to put to it. Keeping a five-pound can on hand is becoming a general practice among Wyoming beekeepers, and will doubtless become nearly universal.

Laramie, Wyoming.

[Every year new methods and conveniences such as this are being brought out, which greatly lighten the beekeeper's work. At the same time, each new development, as a rule, calls for greater skill and intelligence to put into operation. Calcium cyanide should be a great boon to beekeepers, but it must be handled with great care. Thus the industry gradually becomes more and more technical, requiring greater and greater skill and intelligence.—Editor.]

Issued Feb. 15, 1927.

House Flies

An interesting development in the utilization of Cyanogas Calcium Cyanide is the application of "A" Dust for the fumigation of such types of buildings as dairy barns, stores, hogfeed rooms, etc., to control house flies. By using amounts small enough to be within range of safety to the operator and at the same time great enough to result in a lethal dosage for the flies, very satisfactory results have been obtained as may be seen from the following paper by Professor C. O. Eddy, reprinted from the Journal of Economic Entomology, Vol. 20, No. 2, pages 270 to 280, April 1927.

The accompanying photograph from the South Carolina Agricultural Experiment Station Bulletin No. 237 "House Fly Fumigation in Certain Types of Buildings" by C. O. Eddy, April 1927, illustrates the method of applying Cyanogas "A" Dust for this purpose.

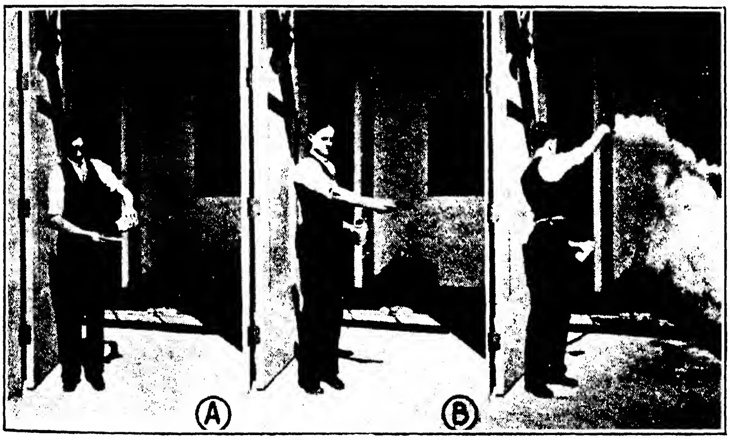


FIG. 1.—A. Pouring Calcium Cyanide on Cupped Cardboard. B. Throwing the Dust. C. The Dust Cloud.

CYANOGAS CALCIUM CYANIDE FOR HOUSEFLY FUMIGATION IN CERTAIN TYPES OF BUILDING

By C. O. Eddy, *S. C. Experiment Station*

ABSTRACT

Hydrocyanic acid gas derived from Cyanogas calcium cyanide has proven an effective and economical fumigant for houseflies at Clemson College, S. C., during the past season, especially in large rooms such as dairy barns, stores, shops, laboratories and under certain conditions in homes. The calcium cyanide was usually applied as a dust cloud thrown vigorously and horizontally from a cupped stiff paper held in the hand. In homes, feed rooms for animals and in other rooms where a dust cloud could not be used or where it was not advisable to have the dust fall to

the floor, the calcium cyanide was applied as a thin film on papers placed in several parts of the room. The normal dosage used in commercial control ranged around ½ ounce per 1000 cubic feet, being slightly less in large rooms with very little leakage and more as the leakage increased, the increase being greatest in the smaller rooms. Night fumigations were more convenient and were usually more effective. The evolution of the gas from the dust clouds was slow enough to allow sufficient time for a thorough application, and the concentration of hydrocyanic acid gas necessary for a lethal dosage for flies is low enough to allow a considerable margin of safety for the operator.

In spite of the fact that it is better to control the maggots of the housefly it is often desirable and sometimes very necessary or urgent to control the adults. The latter condition prevailed at Clemson College, S. C., due to the great abundance of houseflies that existed throughout the last season. Experiments were therefore conducted to determine an economical method of control that not only could be easily applied but would be adaptable to large scale control. Traps and poison solutions had but very little value. Black Flag, commercial pyrethrum and the more recently developed oil sprays had their usefulness under certain conditions but their cost was high.

The experiments reported in this paper represent results for only one season but they were so highly satisfactory it is thought that they will be interesting and useful to other Entomologists. These results were obtained during a hot and very dry summer. The former, at least, may be considered a favorable condition for Cyanogas calcium cyanide as an insecticide.

Object

The object of the experiments reported in this paper was to determine the value of hydrocyanic acid gas derived from Cyanogas calcium cyanide as a housefly fumigant.

Method of Application

Nearly all of the calcium cyanide used in the housefly control tests reported was applied as a dust cloud without the aid of a dust gun. Small amounts of calcium cyanide were successively poured on a strong paper or cardboard that was slightly cupped as it was held in the hand. Each portion of dust was then thrown vigorously and horizontally from the operator so that a dust cloud was formed. The dust was distributed as evenly and uniformly throughout the rooms fumigated as conditions would permit, care being taken that the operator would not have to walk through the dust cloud. The operator has, however, walked through these dust clouds but has always held his breath when doing so. The gas from these clouds of dust spread slowly enough so that there

was always sufficient time to make a thorough application of the poison. The evolution of the gas from the cloud of dust also takes some time, which in addition to the diffusion of the gas in the air, adds to the safety of applying the dust. The question of the margin of safety relative to the concentration of hydrocyanic acid gas necessary for a lethal dosage to flies is included in the section "Discussion."

In certain shops, feed rooms for animals, and other rooms where a dust cloud could not be used or where it was not advisable to have the dust fall to the floor, the calcium cyanide was applied as a thin film on papers placed on the floor so that the hydrocyanic acid gas would uniformly diffuse throughout the room.

Preliminary Tests

A few tests were conducted in a large laboratory in the Agricultural Building where a considerable number of houseflies accumulated each day. This room contained 18,772 cubic feet. It had plastered brick walls and well-fitted windows and doors so that the amount of leakage was small. The tests were usually started at night after the flies had collected in the upper portion of the room and discontinued the next morning. Rooms were well ventilated when opened but were occupied at once.

A dosage of eight ounces of calcium cyanide per 1000 cubic feet was used in the first test. This gave 100% control. A dosage of ⅛ ounce per 1000 cubic feet was then used and many flies survived but enough were killed to indicate that the first dosage was far too high and that a small dosage would probably be sufficient. Three-fourths of an ounce of calcium cyanide was then used and 100% control was again secured. Other tests gave results as follows: .30 ounce gave 100% control, .27 ounce gave 98% control, .24 ounce gave 99% control, and .14 gave from 60% to 70% control. These results indicated that a dosage of slightly less than ½ ounce calcium cyanide per 1000 cubic feet could be used for night fumigation in relatively large rooms having very little leakage. In practice ½ ounce per 1000 cubic feet was used in this room to obtain control.

It was found in certain experiments started before the flies were all in the upper portion of the room, that those concealed in waste paper baskets or other low places often did not receive a lethal dosage. These slowly recovered and were active for a time at least. This indicates that places concealing or protecting flies should have a small portion of the dust scattered in or about them. This will either kill the flies

in situ or drive them out to be killed as they fly in the greater concentration of gas in the higher parts of the room.

The expended residue on the concrete floor was swept up the next morning. This was done by the negro janitor who experienced no discomfort.

Cage Tests

In order to study the effect of the distribution of gas concentrations in different parts of a room being fumigated and the consequent effect on houseflies, fumigation tests were conducted in several laboratories where flies were confined in wire cages placed in different situations. Since the previous experiments primarily concerned flies in the upper portion of the room, this test was conducted chiefly to determine the effect on those in the lower spaces—9 feet and below.

The cages were built of 16 mesh screen wire, 18 inches in height, 15 inches in diameter and with a solid top. Between 100 and 200 flies were caught in each cage by swinging it through their swirling masses, in a feed room where they were abundant. Cloth was then tied over the bottom to prevent escape. Three of the cages containing houseflies were usually placed in each room to be fumigated, one being placed on the floor, one on a table or cabinet with a large top and the third on an electric light cord about 9 feet from the floor. Cages were read about two hours after the tests were discontinued.

The cage experiments were conducted with varying dosages and time exposures. With a dosage of one ounce of calcium cyanide per 1000 cubic feet the control approximated 100% with the exposures of one, two, three, and five hours. The variation in control was very little and was not correlated with the duration of exposure.

With a dosage of ¼ ounce, ½ ounce, or ¾ ounce in the same situation, however, the longer exposures were more effective. The five hour exposure was thus more than twice as effective as the one hour exposure. The ½ and ¾ ounce dosages gave commercial control since they gave 92% and 96% control respectively in the long period tests. In short tests they were inadequate for these low cages. For night fumigations when the flies were in the upper portion of the rooms the results might have been better. The ¼ ounce dosage per 1000 cubic feet was not adequate for control even during the long exposures.

When one ounce of calcium cyanide was used per 1000 cubic feet the results in control obtained in cages at different elevations and in different situations were very uniform. With the lower dosages, however, the contrast was more evident. The highest cages when hanging free in

space had the highest per cent of dead flies. Cages on tables with large tops, on cabinets especially in corners, or near windows often gave less control than that secured in cages on the floor. This indicates that when fumigation is done in the daytime, at least, a small portion of the dust should be scattered in places where the gas does not circulate well, especially if flies are present in these places.

One series of tests was conducted in a small dark room which was unusually high in proportion to the floor size. Control in this room was always very poor. It was thought at first that the damp unplastered brick walls might have been a factor. However, a test was being conducted in another dark room of normal proportions where the walls were unplastered and as moist but where the control secured was uniform with that in the other rooms. It seems, therefore, that because of the unusual height of the room in contrast to its width and length, the hydrocyanic acid gas rose quickly to the upper portions of the room so that only a very small amount of it diffused through the air in the lower part and this was not effective against the flies which were in cages on or near the floor. Thus it may be necessary to increase the dosage in rooms that are excessively high in proportion to floor size, especially if the fumigation is done during the day.

All of these tests were conducted in basement laboratories while the rooms above were occupied. The only ceiling leakage was around pipes that went through to the rooms above. This leakage was never noticed. When rooms were opened after a test some gas escaped into the hall which rose to the third story but this never caused any inconvenience or interfered in any way with the work on that floor.

Tests in Stores

A series of tests was conducted in several grocery stores, restaurants, and drug stores including both brick and frame structures. The volume of the rooms fumigated usually ranged from 10,000 to 15,000 cubic feet. In order that the first experiment might be certain to give satisfactory control one ounce of the calcium cyanide per 1000 cubic feet was used. This gave 100% control, as far as could be ascertained. In the later tests the ½ ounce dosage was used. The control secured was always 100% or very near to it. In one very irregular corner room with many windows and doors a very few flies often escaped when this dosage was used.

Flies caught between screen doors and the main door should be driven out before the fumigated rooms are entered.

The owners and managers of these stores were enthusiastic about the economical and satisfactory housefly control so easily obtained. They often asked for additional fumigations.

Hog Feed Room

A feed room for hogs of about 1000 cubic feet capacity was fumigated a number of times for flies that accumulated in immense numbers each day. It was estimated that 400,000 flies were in it during each fumigation. The room was a frame structure with weatherboards on the outside and ceiling on the inside. Two single windows and a door occupied three sides. There was a large amount of leakage, part of which was closed with wet paper and burlap. The calcium cyanide was applied as a thin film on newspapers. The results of these fumigations may be summarized as follows: .54 ounce of calcium cyanide per 1000 cubic feet gave 50% control of the flies, 1.50 ounce and 2.18 ounce dosages gave 99.9% control and the 3.27 ounces gave 100% control. The one ounce dosage gave commercial control, as in any case it was necessary to repeat the control very often due to the fact that great numbers of flies entered during each day. On windy nights the loss of gas on the windward side was very great, so this may have accounted in part for the necessity of so high a dosage.

House Fumigation

A little additional information was derived by using calcium cyanide in the home of the writer. The dust was applied on newspapers in every case. The dosage was higher because the building was a frame structure and the ceiling above loosely fitted.

Fumigation tests were conducted when rooms below and adjacent were occupied. No tarnishing of walls, or household equipment was ever noted.

Dairy Barns

Fumigation tests were usually conducted at the dairy barns at night, *after the stock had been turned out*, beginning about 10 P. M. and being discontinued about 4 A. M. The illustration, Plate 5, shows the inside of one of these barns. It has three large ventilators about two feet in diameter, a large number of windows fitted only moderately tight, one set of large double sliding doors at either end in the middle and a double height door at one end in each corner. A very large amount of leakage occurred around the doors and some around the windows but this did not necessitate the increase in dosage as it did in the small rooms.

The volume of each barn was the same,—64000 cubic feet. The calcium cyanide was dusted uniformly in the three longitudinal alleys and at the ends. In this room much of the dust cloud remained suspended for some time, some of it even rising several feet and spreading so a very thorough mixture of dust and air took place. This resulted in a rapid evolution of the gas that spread to all parts of the room.

A preliminary test using one ounce of calcium cyanide per 1000 cubic feet was first run without the ventilators being closed or the windows being repaired in order to determine whether control in these large rooms would be possible. The test was highly satisfactory, nearly all of the flies being killed, so the ventilators were closed and the broken window panes replaced. The dosage was then decreased to ½ ounce and, again, nearly all of the flies were killed. The flies that escaped were chiefly around the windows but many of the flies even in these situations were killed. Nearly all the flies were on the ceiling at night, however, so those that did not receive lethal dosages were few.

A dosage of three-fourths ounce with the ventilators open did not give as good control as the half ounce dosage with them closed.

When fumigations were conducted during the day some flies escaped through the leakage around the doors at the ends. Some of the flies near the doors recovered since the toxic gas was around them but for a very short time. Flies in mangers were killed not only more slowly than those on the ceiling but some recovered from the paralysis while a few were only partly affected.

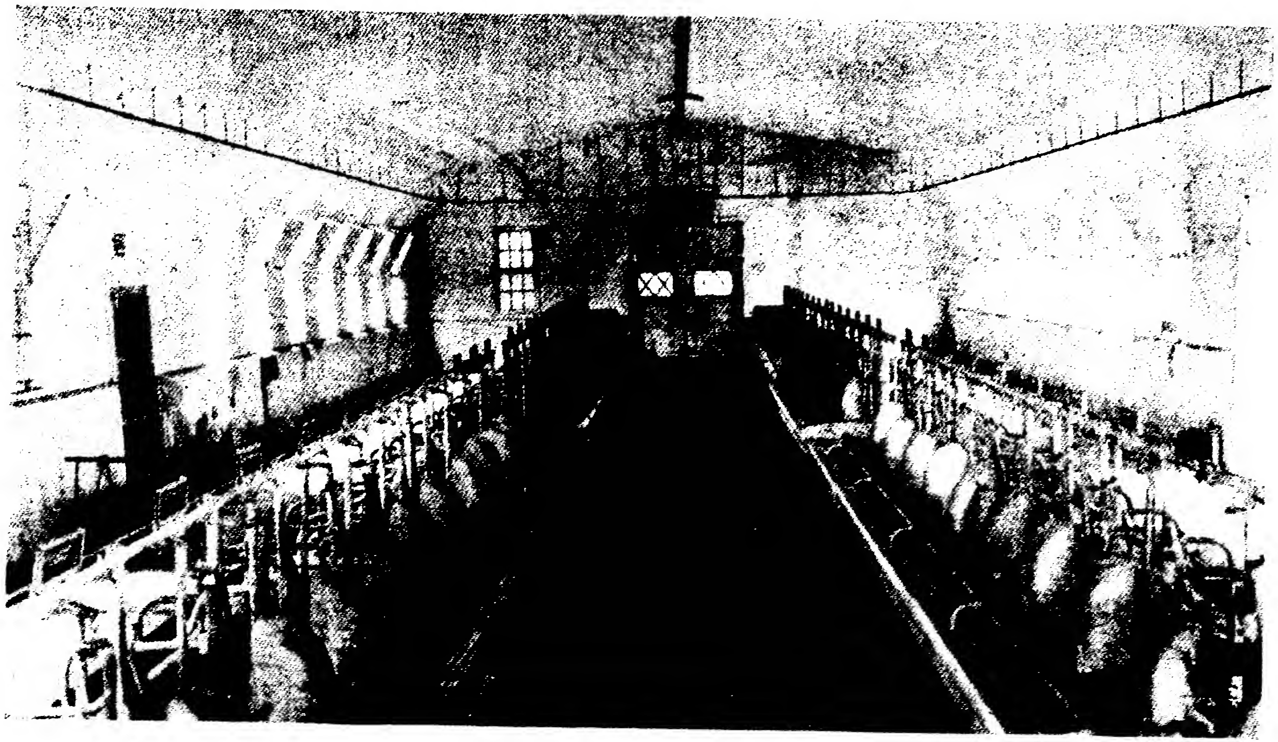
The ½ ounce dosage was used to control flies in the barns in a commercial way after the experiments were discontinued.

Prior to these experiments Black Flag was used twice per week, the application being made from a rotary gun. The duster was operated by a man on top of a tower built on a feed truck that was pushed along the feed alley in the center of the room. The Black Flag cost $2.50 to $3.00. The cost of the two pounds of calcium cyanide for the one-half ounce dosage was 50 cents which represents one-fifth or one-sixth that of the Black Flag fumigation for materials alone. These prices are based on large quantity purchases in both cases. In addition the use of the dust gun and services of the extra man were eliminated.

Discussion

In using calcium cyanide the dangerous properties of the gas evolved should be constantly in mind in spite of the fact that the margin of safety in the concentration of the gas used is considerable. In the Journal of Agricultural Research Vol. XI No. 9, 1917, DeOng says that

PLATE 5



Interior of Dairy Barn Fumigated for House Flies.

the concentration of hydrocyanic acid gas necessary to kill houseflies 100% effectively with an exposure of one hour, is .0046%. This is 4.6 parts per 100,000 of air. Various percentages of the flies were killed with lower concentrations of the gas.

The toxicity of HCN depends chiefly upon two factors: concentration and length of exposure. When liquid hydrocyanic acid gas or HCN generated from sodium cyanide by means of sulfuric acid and water is used, the initial concentration is high. With calcium cyanide these high concentrations are not reached due to the slow evolution. Theoretically, calcium cyanide at a rate of 1 lb. per 1000 cubic feet of air space should produce a concentration of 300 parts per 100,000.

It has been shown by actual experimentation that less than 1/3 of this amount is present in the air at any one time when this dosage is applied as a film on the floor. On this basis, the concentration from the house fly dosage—1/2 oz. per 1000 cubic feet—would not be more than 3.1 parts per 100,000 at any one time, at least near the floor, and would be less than that during most of the fumigation. The concentration near the ceiling and in the dust cloud itself was undoubtedly higher, as the flies were killed, but even here the margin of safety to man would be great.

Due to its great properties of diffusion, HCN soon becomes dissipated even in comparatively tight buildings. It was largely due to this reason that HCN was not successful as a war gas. The danger due to the presence of gas in rooms fumigated at the low dosages recommended at the time of airing out would be very slight.

Since the concentration of the gas near the floor is never high except for a very brief time, this increased the margin of safety still more.

In the Journal of Hygiene Vol. XXI No. 3, May 1923, Liston & Goré state: ". . . . it is difficult to obtain a sufficient concentration of the gas in the open air to poison men. It is pointed out that this experience accorded with that obtained during the war when hydrocyanic acid gas was used as a poison gas. It was stated that men are comparatively less susceptible to the poison than animals. Birds, for example, are very susceptible. Among mammals, dogs are killed in half an hour when exposed to about 8 parts of gas in 100,000 parts of air; cats require 12 parts; rabbits, 15 parts; rats, 20 parts to kill them; while goats and monkeys require nearly 25 parts. A man requires at least as much as a monkey to kill him." According to this it then requires several times as great a concentration of the gas to kill goats, monkeys and probably man as to kill flies.

Liston and Goré further state: ". . . . In low concentrations the gas causes a very disagreeable sensation in the throat and eyes so it is avoided by persons brought in contact with it. A man becomes unconscious only when exposed to higher concentrations, and, if the concentration which just causes unconsciousness is not increased, a comparatively long latent period supervenes before death. A person who becomes unconscious when exposed to moderate concentrations of hydrocyanic acid gas recovers rapidly when placed in the open air. The gas acts much like an anaesthetic such as chloroform. However, exposures to high concentrations may cause instant death, probably through action on the heart."

If slight effects are ever felt when handling the calcium cyanide they can be counteracted by occasionally inhaling ammonia or ammonium carbonate.

In fumigating the stores six mice were killed by the one ounce dosage in one room, one in another and still another in a third room. Two mice were killed in one store with the one-half ounce dosage. One rat was killed during the tests at the laboratories. The control of rodents can be facilitated by distributing some of the dust near the places where they are or may be concealed without in any way reducing the efficiency of the housefly control. Bats were also quickly killed.

While the figures of paragraph 3 under "Discussion" are only approximations, they show that, when the ½ oz. dosage is used, the concentration of gas required for the 100% kill of flies as derived by DeOng does not occur near the floor for a very long period at least and then possibly not uniformly. The gas, however, does become concentrated in the places where flies congregate for the night and if the rooms are reasonably tight will go above the 3.1 and probably above the 4.6 parts per 100,000 of air since they are effectively killed.

A dust gun may be used in applying the dust but it is not necessary. In case a dust gun is employed it should be thoroughly cleaned each time after it is used in order to prevent corrosion.

Domestic animals were never kept in the buildings during any of the fumigations and *fumigations should never be conducted with these present.*

That the greatest kill occurred in the first half hour was shown from observations made through the windows. Where conditions are such that only a few hours are available for fumigation, exposures of two hours for large rooms should give good results.

Conclusions

1. The experiments reported indicate that at least for the conditions that prevailed at Clemson College, S. C., during the last summer, the dosage of calcium cyanide needed in housefly fumigation ranges around ½ ounce per 1000 cubic feet, being slightly less in large rooms with very little leakage when fumigating at night when the flies are in the upper parts of the rooms and more as the amount of leakage increased, the increase being greatest in the smaller rooms. During the day the flies are likely to be in lower and more protected places and an increased dosage may be necessary especially for small spaces. Very large rooms even with considerable leakage can be successfully fumigated with the ½ ounce dosage, but smaller rooms of similar structure often required the one ounce dosage and sometimes more. It is believed that a dosage will have to be derived for each situation according to size and shape of the room, the amount of leakage in the walls and perhaps other factors. The ½ ounce dosage should prove a good basis for the first estimate with conditions similar to those in these experiments.

2. The margin of safety seems to be very great both from the practical and from the theoretical standpoint. Dosages higher than one ounce per 1000 cubic feet would probably never be warranted and should not be used unless further tests indicate them to be practical and economical.

3. Domestic animals should not remain in the rooms being fumigated in spite of the fact that the concentration of the gas might not constitute a lethal dosage. Canaries, however, would probably be killed while dogs which are very susceptible to HCN also might be. Rats, bats and mice were killed in the experiments.

4. Fumigations at night are usually more effective and more convenient.

5. Better results were usually secured in experiments where the cloud method of application was used rather than the film method.

6. Scattering some of the dust around places that may conceal rodents will give better kill of rats and mice and will not decrease the control of the houseflies.

7. Care should be taken in handling the calcium cyanide to prevent loss of the gas and to prevent corrosion of metal surfaces with which the dust may come in contact.

8. This method of housefly control is especially useful in large rooms such as dairy barns, stables, stores, bakeries, packing houses, store-rooms and in many other places where other methods of control are not practical and economical.

9. While preliminary tests showed that this method might be applicable to household use under certain conditions, it should not be recommended generally for this purpose. The possibilities of unfortunate circumstances arising from placing the material in the hands of people unacquainted with the nature and use of poisonous insecticides is far too great to warrant its recommendations for this use.

MR. PEREZ SIMMONS: Are there any advantages in scattering the dust through the air to spreading it on the floor?

MR. C. O. EDDY: We seemed to get more effective control from using the dust. I don't know what all the factors involved are, but possibly there is more gas involved. Anyhow in the comparison of the different experiments we got better results from those.

MR. PEREZ SIMMONS: In using it in restaurants, wouldn't it upset the whole place?

MR. C. O. EDDY: In restaurants we usually do use it as a film on papers on the floor.

MR. G. A. DEAN. The Dairy Husbandry Department of the Kansas State Agricultural College has been practicing for some two months by using the dust in their big milk house. They simply close the building up tightly just a few minutes before they are ready to bring the animals in and start down at one end with the dust gun and go clear through to the other end. Then they bring in the milch cows. They don't sweep up the dust or anything. There is no inconvenience to any of the animals. The flies do not bother the animals.

Another interesting thing that developed there is that after they have opened the house and are in there milking the cows, the flies lighting on the walls and around are still being killed. I just suggest that there is an adsorption of gas by the plaster there, or by the wood, that is still killing flies after the place has been opened.

MR. C. O. EDDY: There is one thing I did not mention and that is in the fumigation in the dairy barn the cost was reduced by one-fifth or one-sixth in comparison to the use of pyrethrum which was used prior to the starting of these experiments, and so the dairy barns began to use the calcium cyanide entirely in place of the pyrethrum and did away with the use of the dust gun. We found it was not necessary, although it is perfectly all right to use it.

MR. C. A. WEIGEL: How long a barn was it?

MR. C. O. EDDY: About 60 feet long, I would say, and some 25 feet high.

Issued May 25th, 1927.

Cyanogas Calcium Cyanide for the Fumigation of Flour Mills

By

Stanley W. Bromley, Entomologist
American Cyanamid Sales Company

INTRODUCTION

Fumigation with hydrocyanic acid gas has, for a number of years, been recognized as a standard method of controlling insect pests in flour mills. The rapidity with which this gas destroys insect and rodent life, and the speed and convenience attendant upon its use have been important factors in its widespread adoption. This quickly-acting toxicity, however, with the consequent danger to the operator has been in the past a factor which has impeded the development of its use where there is any possibility of its affecting human life.

A method whereby hydrocyanic acid gas might be introduced into a space to be fumigated in such a way that a lethal concentration of the gas would not be rapidly reached, was a great desideratum. Of all the cyanide compounds which could be utilized for this purpose, Cyanogas Calcium Cyanide—due to its property of liberating hydrocyanic acid gas comparatively slowly upon exposure to atmospheric moisture—seemed to possess this desired quality to the most promising degree.

A method of application which might be employed by the miller, himself, was desired, and it was for the fumigation of the small mill—for which Cyanogas appeared particularly adapted—that the tests were conducted.

A series of tests to determine the efficiency and practicability of Cyanogas for this purpose were conducted by the writer in cooperation with certain experimenters during the 1927 season. To the various workers who have cooperated in these tests, the writer wishes to express his sincere gratitude. The data and conclusions obtained from these tests together with data obtained from certain other tests are presented in this paper.

PRINCIPLES OF *HCN* FUMIGATION

In all types of mill fumigation where HCN is the fumigant, the fundamental principles are the same, regardless of the source of the gas whether it be potassium cyanide, sodium cyanide, liquid HCN, or calcium cyanide. These general principles may be classified under the following headings:

1. Leakage
2. Penetration
3. Temperature

Leakage. Hydrocyanic acid gas has great powers of diffusion and will "leak" out of a building rapidly if any openings are present leading to the outside air. Where excessive leakage occurs, the inside concentration of gas may be so reduced that a failure to obtain a kill of the insects may result.

Leakage is a variable factor, depending largely upon the construction of the building. A modern cement building may be so tight as to require very little extra labor in sealing whereas an old wooden building may be so loosely constructed as to be unfit for fumigation unless a great deal of work is expended in sealing it. Labor expended beyond a certain point in making a building tight is, however, hardly warranted. Under average conditions, it is not necessary to seal over unbroken windows; but all cracks and spaces in the walls leading to the outside, all broken panes of glass, vents, spaces between doors and floors, around window frames and similar locations should be sealed over with paper. Blocking such openings with burlap or sacking does not make them sufficiently tight.

In some cases, particularly around basement doors, a few shovelfuls of earth were thrown around the door, closing the space between the door and the floor.

Penetration. It is a well known fact that HCN penetrates flour with difficulty and insects hidden in flour beyond a certain depth usually survive a fumigation.

Dean (Kansas Agricultural Experiment Station Bulletin No. 189, July, 1913, p. 190) states that in mill fumigation, "HCN will not penetrate flour and mill products much beyond one inch, and in many places, particularly near the floor, not even one inch."

The necessity of thoroly cleaning the mill, prior to the fumigation is therefore very evident. It is the experience of professional fumigators that the principal cause of unsatisfactory fumigations is the lack of adequate cleaning of the mill previous to the fumigation.

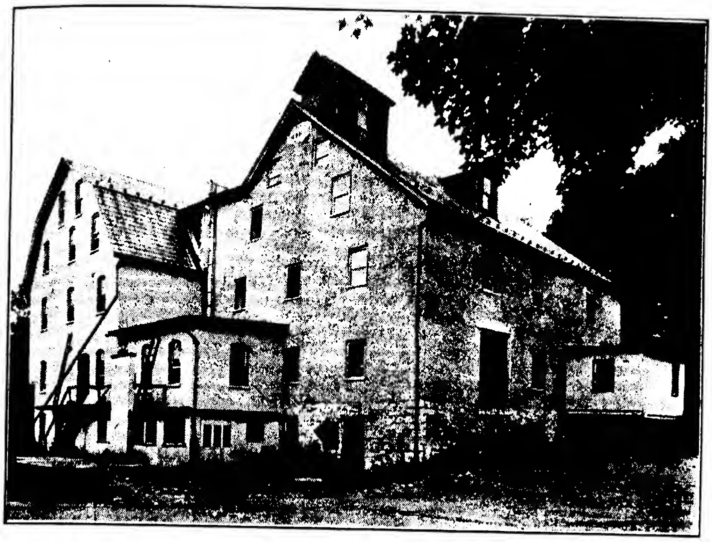


Fig. 7-3. A Country Flour Mill in the Eastern United States.

Fig. 8-3. Interior of a Small Mill. The Machinery is generally infested with the Mediterranean Flour Moth and the Confused Flour Beetle.

To insure as complete a cleaning as possible, the mill should be gone over thoroughly and all webbing, waste, and refuse flour in elevators, boots, packers, purifiers, conveyors, reels, sifters, etc., should be removed from the mill and burned. The machinery should be run empty for thirty minutes and the conveyors and boots blown out by compressed air.

The same principle applies to the penetration of closed-off compartments. Experience has shown that insects in parts of the mill machinery which were not opened up, frequently survive. To insure kills in such locations, every part of the mill machinery should be opened up to allow direct access of the gas. Every slide door, conveyor top, cap, and panel should be opened or removed.

In general, the removal of the elevator heads is not advised where the sodium cyanide method is used as the hot gas rises rapidly up the elevators and forms a strong concentration at the heads. In the Cyanogas tests, the elevator heads were removed in some cases and in others, not. It was concluded that where a heavy infestation of the Flour Moth occurs, it would be advisable, particularly in the case of wooden tops, to remove the elevator heads and place them on the floors where Cyanogas may be applied directly into them during the spreading. After the fumigations, the elevator heads were then thoroughly cleaned before replacing.

Temperature. The higher the temperature, the more quickly are insects killed by HCN. This is supposedly due to the increased activity and rate of respiration brought about by heat. Best results are obtained when the temperature is 65°F or over but fumigations with HCN may be conducted with a reasonable assurance of success whenever the temperature is high enough for the insects to be in an active state.

ADDITIONAL FACTORS AFFECTING THE USE OF CYANOGAS

In addition to the factors just considered, (1) *Relative Humidity* and (2) *Distribution of material* must be considered where Cyanogas Calcium Cyanide is employed.

Relative Humidity: The rate of evolution of HCN from Cyanogas Calcium Cyanide is dependent upon the relative humidity. As may be seen from fig. 1—Section G page 5, when the relative humidity is 35% or below, the evolution of HCN from Cyanogas is considerably reduced. In many mills, the air is very dry and in some cases would be even under 35%. Where a low humidity occurs, it is advisable that some

means be taken for increasing the humidity. Experiments on this point were conducted and it was found that the relative humidity in a mill might be increased somewhat by either sprinkling water over the floors 2 or 3 hours before the Cyanogas was applied or by hanging up about a dozen moist sacks to a floor in the building about 3 hours previous to the fumigation and closing the mill to hold the moisture.

The top floor is usually the driest and in many cases this may be the only floor requiring an artificial increase in humidity.

In a tight, modern, cement building, raising the humidity is rarely necessary as the relative humidity will rise considerably following the closing of the building. The accompanying chart (Fig. 6-3) plotted from data obtained by Mr. Schenk at Kansas City brings out this point. Here are represented relative humidity data taken at intervals both inside and outside a mill which had been closed as if for fumigation. No artificial means of increasing the relative humidity was employed.

Distribution of Material: As the liberation of HCN from Cyanogas is dependent upon the atmospheric moisture, it follows that the greater the surface exposed, the more complete will be the reaction. For this reason, it is necessary that Cyanogas be spread very thinly and evenly so that the maximum efficiency may be obtained from the material.

EXPERIMENTAL FUMIGATIONS

The experimental fumigations are summarized in Table I.

The insects encountered in these tests were the principal mill insects of economic importance and included the following:

The Mediterranean Flour Moth *(Ephestia kuehniella* Zell.)

The Confused Flour Beetle *(Tribolium confusum* Duv.)

The Rust-Red Flour Beetle *(Tribolium ferrugineum* Fabr.)

The Cadelle *(Tenebroides mauritanicus* L.)

The "Meal Worms" *(Tenebrio molitor* L. and *T. obscurus* Fabr.)

The Saw-toothed Grain Beetle *(Oryzaephilus surinamensis* L.)

The Square-necked Brain Beetle *(Silvanus gemellatus* Duv.)

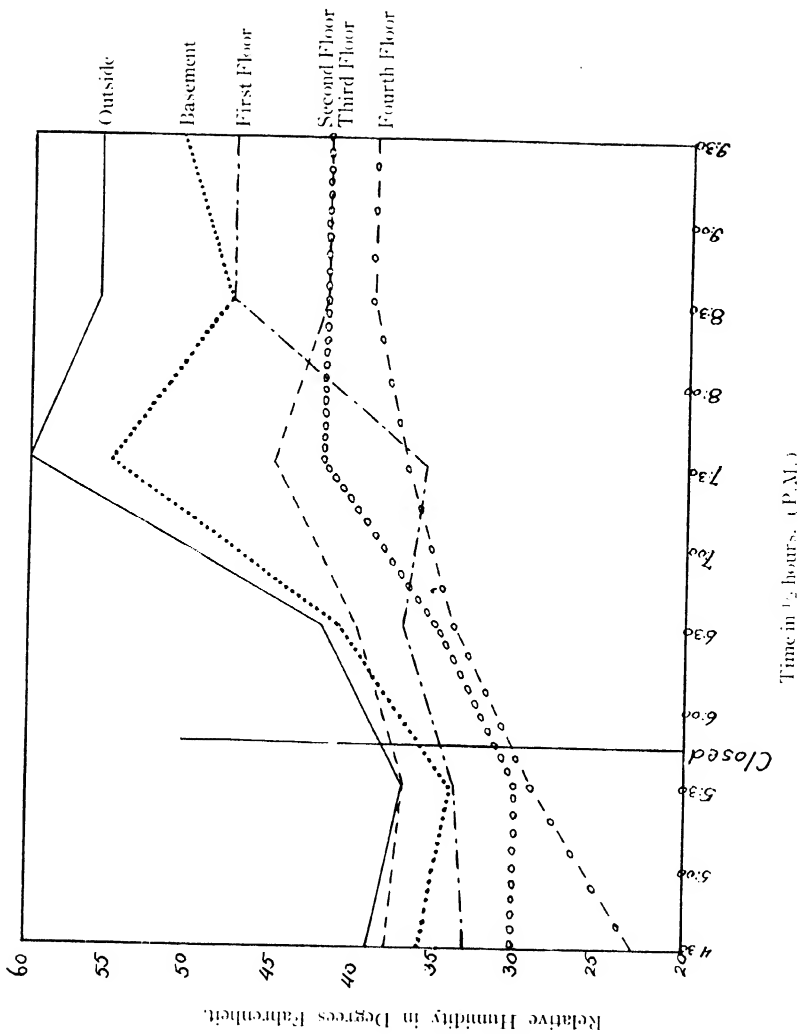


Fig. 9-3. Chart Showing Rise of Relative Humidity in a Closed Building.

The Flat Grain Beetle *(Crypturgus pusillus* Gyll.)

The Black Fungus Beetle *(Alphitobius piceus* Oliv.)

The Two-banded Fungus Beetle *(Alphitophagus bifasciatus* Say.)

The Drug Store Beetle *(Sitodrepa panicea* L.)

The Black Carpet Beetle *(Attagenus piceus* Oliv.)

The Larder Beetle *(Desmestes lardarius* L.)

A species of *Anthrenus* was also noted.

In addition, the following true grain insects were found (in exposed locations) in several mills.

The Granary Weevil *(Sitophilus granarius* L.)

The Rice Weevil *(Sitophilus oryza* L.)

The Angoumois Grain Moth *(Sitotroga cereallela* Oliv.)

A control of insects infesting grain in bulk can not be obtained by a general fumigation with hydrocyanic acid gas because of the difficulty of penetration. The problem of the fumigation of grain in bulk with HCN has been solved by the Cyanogas method of Grain Fumigation (Section 3 pages 37-73.)

A general fumigation with HCN kills the adults of the Angoumois grain moth and kills or stupefies the majority of the exposed adult weevils. Where Cyanogas is used, most of the latter will be swept up with the residue after the fumigation and thus disposed of, but it has also been noted in the case of the weevil, that the majority of the individuals reviving after receiving a heavy charge of HCN are greatly weakened and soon die. This phenomenon has not, however, been noted in the case of the mill beetles as the Tribolium or the Cadelle, which if not killed outright, live as long as the checks after reviving.

A control of practically 100% of the other insects in the list by a general fumigation with HCN has been demonstrated, except in the case of the Cadelle in wooden mills where many pupae in the tunnels in the wood-work may survive.

The mill insects differ considerably in susceptibility to HCN. Dean (Kansas Agricultural Experiment Station Bulletin No. 189, 1913, p. 177) states that all stages of the Mediterranean Flour Moth, including the eggs, if not covered with more than one inch of flour are killed by hydrocyanic acid gas. This has been confirmed by the present studies with Cyanogas. In general, the Mediterranean Flour Moth is the most readily killed while the beetles, particularly the Cadelle and the Flat Grain Beetle, are much more resistant. As a rule the adult insects are more readily killed than the pupae or the larvae.

TABLE I

Exp. No.	Date	Location and Experimenter	Types of Cyanogas Used & How Applied	Construction of Building	At Time of Application: Temp.	At Time of Application: Rel. Hum.	Method of Raising Humidity	Pests	Results	Remarks
1	6-23-24	Maryland (P. D. Sanders)	Granular & Flakes on papers	Not Reported	Not recorded	Low	None	Med. Flour Moth	Unsatisfactory	50% Kill
								Tribolium	Unsatisfactory	Less than 50% kill.
2	10-17-25	Texas (J. L. Ressler)	"A" Dust on papers	Galv. Iron (Warehouse)	74°F	66%	None	Med. Flour Moth	Unsatisfactory	Adults flying in Bldg. when opened
								Oryzaephilus	Unsatisfactory	
								Sitophilus	Unsatisfactory	
								Mice	Satisfactory	
3	7-31-26	Kansas (R. C. Smith)	Granular on papers	Stone: tight	86°F	44%	None	Silver fish	Satisfactory	Cyanide probably not completely reacted.
								Cockroaches	Satisfactory	
								Mice	Unsatisfactory	
								Grain Weevils	Unsatisfactory	
4	12-24-26	New Zealand	G-Fumigant on floors from tins.	Brick: tight	Not recorded	High	None	Med Flour Moth	Satisfactory	
								Wood-borer	Satisfactory	
								Beetles	Satisfactory	
								Rats and Mice	Satisfactory	
5	1-8-27	New Zealand	G-Fumigant on floors from tins.	Tight	Not recorded		None	Med. Flour Moth	Satisfactory	
								Weevil	Satisfactory	
								Rats and Mice	Satisfactory	
6	5-14-27	Virginia (Mr. Cagle & S. W. Bromley)	G-Fumigant on floors by shovel.	Wooden: loose	63°F	64%	Sprinkling floors	Med. Flour Moth	Unsatisfactory	Only 77% larvae killed; many alive.
								Granary Weevil (in open)	Unsatisfactory	Not more than 20%.
								Tenebrio	Satisfactory	Only a very few alive; many dead.
								Cadelle	Unsatisfactory	Many alive.
7	5-21-27	Virginia (G. W. Underhill & S. W. Bromley)	G-Fumigant on floors by shovel.	Wooden Very loose	87°F (top floor)	43%	Sprinkling floors	Med. Flour Moth	Satisfactory	None in evidence a month later.
								Granary Weevil	Satisfactory	(in open)
								Tenebrio	Satisfactory	2 larvae alive; many dead.
								Tribolium	Unsatisfactory	

Exp. No.	Date	Location and Experimenter	Types of Cyanogas Used & How Applied	Construction of Building	At Time of Application T	R.H.	Method of Raising Humidity	Pests	Results	Remarks
8	5-28-27	Massachusetts (A. I. Bourne & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight	63°F (top floor)	50%	Sprinkling floors	Med. Flour Moth	Satisfactory	No adults or larvae alive.
								Tenebrio	Satisfactory	Heavy infestation.
								Cadelle	Satisfactory	Many dead; none alive.
								Mice	Satisfactory	
9	6-4-27	N. Carolina R. W. Leiby & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight	74°F (top floor)	61%	Moistened sacks on 3 top floors.	Med. Flour Moth	Satisfactory	None alive.
								Tribolium	Unsatisfactory	Hundreds dead but many alive.
								Tenebrio	Unsatisfactory	A number alive near doors.
								Alphitobius	Unsatisfactory	Hundreds dead but many alive.
								Mice	Satisfactory	
10	6-4-27	N. Carolina (R. W. Leiby & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight	75°F (top floor)	66%	Few moistened sacks on upper floors.	Med. Flour Moth	Satisfactory	
								Tribolium	Satisfactory	Thousands dead; only a very few alive.
								Alphitobius	Satisfactory	None alive.
								Cadelle	Satisfactory	None found alive.
								Mice	Satisfactory	Many dead.
11	6-4-27	N. Carolina (R. W. Leiby & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight	75°F (top floor)	66%	A few moist sacks on top floor.	Tribolium	Satisfactory	None found alive.
								Tenebrio	Satisfactory	None found alive.
								Alphitobius	Satisfactory	Very few—all dead.
								Attagenus	Satisfactory	None alive.
								Cadelle	Satisfactory	None alive.
								Mice	Satisfactory	Several dead.
12	6-11-27	Ontario Prov. Canada (C. H. Curran & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight (Warehouse)	66°F	44%	None	Tenebrio	Unsatisfactory	Low kill: Many alive.
								Cadelle	Unsatisfactory	Many revived.
								Dermestes	Satisfactory	Many dead: None alive or revived.
13	6-11-27	Ontario Prov. Canada (C. H. Curran & S. W. Bromley)	G-Fumigant on floors by shovel.	Brick: tight	67°F	58%	Moist sacks.	Med. Flour Moth	Satisfactory	All stages killed.
								Tenebrio	Satisfactory	Many dead: 2 alive.
								Cadelle	Satisfactory	All adults dead: 1 larva dead: None alive.
								Crypturgus	Satisfactory	Many dead: None alive.
								Mice	Satisfactory	

TABLE I–(*Cont'd.*)

Exp. No.	Date	Location and Experimenter	Types of Cyanogas Used & How Applied	Construction of Building	At Time of Application: Temp.	At Time of Application: Rel. Hum.	Method of Raising Humidity	Pests	Results	Remarks
14	6-18-27	Pennsylvania (H. B. Kirk & S. W. Bromley)	G-Fumigant on floors by shovel.	Wood: loose	74°F	43%	Moist sacks.	Med. Flour Moth	Satisfactory	
								Tenebrio	Satisfactory	Many dead: 2 revived.
								Cadelle	Satisfactory	Many adults dead: 1 live larvae.
								Rats	Satisfactory	
								Mice	Satisfactory	Many dead all over mill.
15	6-25-27	N. Carolina (R. W. Leiby & J. A. Harris)	G-Fumigant on floors by shovel.	Brick: fairly tight	Not re-corded	High (out-side)	Moist sacks on upper floors.	Med. Flour Moth	Satisfactory	
								Tribolium	Satisfactory	
								Cadelle	Satisfactory	
								Silverfish	Satisfactory	
								Angoumois Grain Moth (in stored corn)		Adults killed: Control not expected due to lack of penetration.
16	6-25-27	N. Carolina (R. W. Leiby & J. A. Harris)	G-Fumigant on floors by shovel.	Brick: fairly tight (Warehouse)	Not re-corded	High (out-side)			Reported by owner as being satis-factory.	A few live insects noted.
17	7-9-27	Virginia (G. W. Underhill & S. W. Bromley)	G-Fumigant on floors by shovels and scoops.	Brick: fairly tight	78°F	75%	Moist sacks.	Med. Flour Moth	Satisfactory	All stages killed.
								Tribolium	Satisfactory	Thousands dead—a very few alive.
								Tenebrio	Satisfactory	Very many dead: 3 alive near outside door stuffed with sacks.
								Cadelle	Satisfactory	Many adults and larvae dead: 1 live larva in packer.
								Granary Weevil	Satisfactory	About 50 (either dead or stupefied) Swept out with residue.
								Crypturgus	Satisfactory	336 collected: None revived.
								Angoumois Grain Moth		Adults killed emergence from bins continued.
								Mice	Satisfactory	Many dead all over mill
								Rat	Satisfactory	Few dead on [illegible]

Exp. No.	Date	Location and Experimenter	Types of Cyanogas Used & How Applied	Construction of Building	Te At Time of Application	Rel Hu	Method of Raising Humidity	Pests	Results	Remarks
18	7-9-27	Pennsylvania (H. B. Kirk & G. Stuart)	G-Fumigant over floors by shovel.	Wooden	Not recorded		Moist sacks.	Med. Flour Moth	Satisfactory	
								Tribolium	Unsatisfactory	Many alive.
19	7-9-27	Pennsylvania (H. B. Kirk & G. Stuart)	G-Fumigant over floors by shovel.	Stone	Not recorded		Moist sacks.	Med. Flour Moth	Satisfactory	
								Tenebrio	Satisfactory	Few alive in pile of refuse flour.
								Cadelle	Satisfactory	
20	7-16-27	Pennsylvania (H. B. Kirk & S. W. Bromley)	G-Fumigant over floors by shovel.	Stone fairly tight	80°F	76%	Moist sacks.	Med. Flour Moth	Satisfactory	
								Tenebrio	Satisfactory	
								Granary Weevil	Satisfactory	
								Cadelle	Satisfactory	
								Drug Store Beetle	Satisfactory	
								Attagenus	Satisfactory	Numerous dead: None alive.
								Silvanus gemellatus	Satisfactory	Numerous dead: a few alive under paper at door.
								Mice	Satisfactory	About 50 dead found in various parts of the mill.
								Rats	Satisfactory	2 large dead rats found.
21	7-30-27	Minnesota (G. Schenk)	G-Fumigant on papers	Shiplap covered with metal sheeting.	Not recorded		None	Med. Flour Moth	Satisfactory	None found alive Later live adults noted in closed spouts.
								Tenebrio	Unsatisfactory	Larvae and adults alive.
								Cadelle	Unsatisfactory	Live larvae and adults in basement and 1st floor.
								Tribolium	Unsatisfactory	Live adults in basement, 1st and upper floors, (Mill would not pass inspection.)
22	8-6-27	Minnesota (G. Schenk)	G-Fumigant over floors with shovel.	Shiplap covered with metal sheeting.	Not recorded		Wet sacks and live steam.	Tribolium	Unsatisfactory	Several alive in 1st floor and in basement.
								Tenebrio	Unsatisfactory	ditto.
								Cadelle	Unsatisfactory	ditto.

TABLE I–(*Cont'd.*)

Exp. No.	Date	Location and Experimenter	Types of Cyanogas Used & How Applied	Construction of Building	At Time of Application: Temp.	At Time of Application: Rel. Hum.	Method of Raising Humidity	Pests	Results	Remarks
23	7-30-27	Minnesota (G. Schenk)	G-Fumigant over floors with shovel.	Shiplap	74°F	50%	None	Med. Flour Moth	Satisfactory	None alive: Many dead.
								Tenebrio	Satisfactory	None alive.
								Cadelle	Satisfactory	Many dead.
24	8-4-27	Minnesota (G. Schenk)	G-Fumigant over floors with shovel.	Brick (Warehouse)	71°F	45%	None	Crypturgus	Satisfactory	None alive.
								Cadelle	Satisfactory	Many dead.
								Tenebrio	Satisfactory	Many dead: 2 adults 1 larvae alive.
25	8-4-27	Minnesota (G. Schenk)	G-Fumigant over floors with shovel.	Brick loosely constructed	72°F	50%	Wet sacks.	Tenebrio	Unsatisfactory	Many adults and larvae alive.
26	8-4-27	Minnesota (G. Schenk)	G-Fumigant over floors with shovel.	Pit and tunnel room.	Not taken		None	Tenebrio	Satisfactory	None alive: many dead.
27	10-1-27	Missouri (G. Schenk & S. W. Bromley)	G-Fumigant over floors with shovel.	Modern tightly constructed.	78°F (top floor)	67%	None	Tribolium	Satisfactory	

The resistance of the pupae is probably due to the fact that they occur in more protected locations than the other stage, and are relatively inactive.

In checking the results of a fumigation, the number and location of live insects noted after the fumigation was chosen as a criterion rather than the % control. The percentage of control is nearly impossible to estimate and furthermore would hardly represent a satisfactory standard according to the ordinary conception. A 98 or 99% kill might not be satisfactory where hundreds of thousands of insects were concerned as enough individuals even at these percentages might remain to bring about a speedy reinfestation. A kill of practically all exposed insects and a great majority of insects in protected places was considered as satisfactory. Pasteboard pill boxes containing mill insects were also placed in different parts of the mill as checks in some of the tests. The presence of an infestation after the fumigation in such places as conveyors, half-filled with flour, which were overlooked and un-opened during the clean-up were not considered in the estimation of the results. If such conditions are found, they should be treated locally with Cyanogas after the fumigation and the infested flour destroyed.

APPLICATION

TYPE OF CYANOGAS USED: Fumigations of enclosed spaces have been tested with the following types of Cyanogas Calcium Cyanide: A-Dust, G-Fumigant, Granular, and Flakes. The liberation of HCN from the flakes is too slow for best results. The use of A-dust in large amounts in enclosed spaces is attended with danger or at least discomfiture to the operator due to the rather rapid evolution of HCN and the tendency of the material to rise in clouds, and should be attempted only by experienced operators equipped with gas masks. The G-fumigant, particles of which are about the same texture as sea sand, was found to be most satisfactory for mill fumigation as it was easy to handle and the rate of evolution of gas allowed a satisfactory margin of safety to the operator, working away from the source of the gas.

METHOD OF APPLICATION: The following methods of applying Cyanogas have been tested.

1. Scattering the material from the container on papers.
2. Scattering the material from the container directly on the floor.

3. Broadcasting the material over the floors by means of a shovel or scoop.

Broadcasting the material directly over the floors by means of a shovel was considered the most satisfactory method. The scattering of the material as thinly and evenly as possible over a wide area in as short a space of time as possible was desired and these conditions are fulfilled by this method.

The operation is best performed by two men, one pouring the material on to the shovel from the container or a bucket and the other broadcasting the material with an even side sweep of the shovel ending in a flip. The spreading is started at the end of the room farthest from the exit, and continued toward the exit, making the application successively on each floor from the top floor down. The operation has been very efficiently performed by five men, two carrying the buckets, two broadcasting the material and one man at the stairway or elevator pouring the Cyanogas into the buckets.

The concentration of HCN for a part of the fumigation period, at least, appears to be greatest in the immediate vicinity of the Cyanogas, hence the nearer the material to the foci of heavy infestation, the quicker and better the kill. Particular pains should therefore be taken to scatter the Cyanogas in back of, in under, and around the mill machinery and in elevator boots or under open spouts and packers and other places where insect infestations are known to exist, as well as in corners of rooms and directly over, between, and around piles of sacks.

In some of the tests, in certain conveyors or bins, where difficulty of penetration might exist, small cloth sacks containing a few ounces of Cyanogas were placed and removed after the fumigation.

TIME REQUIRED FOR APPLICATION: The accompanying table (Table II) indicates the length of time required for the application of Cyanogas in the treatment of a mill.

DOSAGE

Tests were conducted with various dosages. A tabulation of the various dosages is shown in Table III. A dosage of 1½ lbs. per 1000 cu. ft. was found to give satisfactory results in tight mills. As, however, mills vary greatly in degree of tightness of construction, a dosage of 2 lbs. per 1000 cu. ft. was considered advisable for general use.

TABLE II

Time Required for Application of Cyanogas in Mills

Exp. No.	No. of Operators	Size of Building	No. Lbs. Used	Time Required For Application
4	3	610,000 cu. ft.	625	40 minutes
6	4	125,000 cu. ft.	125	20 minutes
7	2	57,600 cu. ft.	115	14 minutes
8	2	200,000 cu. ft.	295	16 minutes
9)		(118,680 cu. ft.	121)	
10)	6	(151,800 cu. ft.	226)	25 minutes
11)		(60,720 cu. ft.	122)	
12)	3	(68,000 cu. ft.	70)	25 minutes
13)		(62,591 cu. ft.	97)	
14	2	75,600 cu. ft.	175	25 minutes
17	6	800,000 cu. ft.	1200	50 minutes
20	4	100,000 cu. ft.	200	25 minutes
24)		(83,700 cu. ft.	125)	
25)	4	(141,552 cu. ft.	215)	7 minutes
26)		(5,000 cu. ft.	15)	

TABLE III

DOSAGE

Exp. No.	Dosage (Lbs. per 1000 cu. ft.)	Amt. Used Lbs.	Results*	Remarks
No. 9	1	121	Unsatisfactory	
No. 6	1	125	Unsatisfactory	
No. 1	1	175	Unsatisfactory	
No. 5	1	350	Satisfactory	
No. 21	1-3/8	110	Unsatisfactory	
No. 22	1-1/2	120	Unsatisfactory	
No. 25	1-1/2	215	Unsatisfactory	
No. 3	1-1/2	250	Unsatisfactory	
No. 18	1-1/2	300	Unsatisfactory	
No. 13	1-1/2	97	Unsatisfactory	
No. 24	1-1/2	125	Satisfactory	
No. 23	1-1/2	160	Satisfactory	
No. 10	1-1/2	226	Satisfactory	
No. 8	1-1/2	295	Satisfactory	
No. 17	1-1/2	1200	Satisfactory	
No. 7	2	115	Unsatisfactory	Building too open
No. 16	2	78	Satisfactory	
No. 19	2	100	Satisfactory	
No. 11	2	122	Satisfactory	
No. 20	2	200	Satisfactory	
No. 27	2	230	Satisfactory	
No. 15	2	272	Satisfactory	
No. 14	2-1/3	175	Satisfactory	
No. 26	3-1/3	175	Satisfactory	

*Where the results on one or more species of mill insects were unsatisfactory, the results in this column and in Table IV are listed as "unsatisfactory."

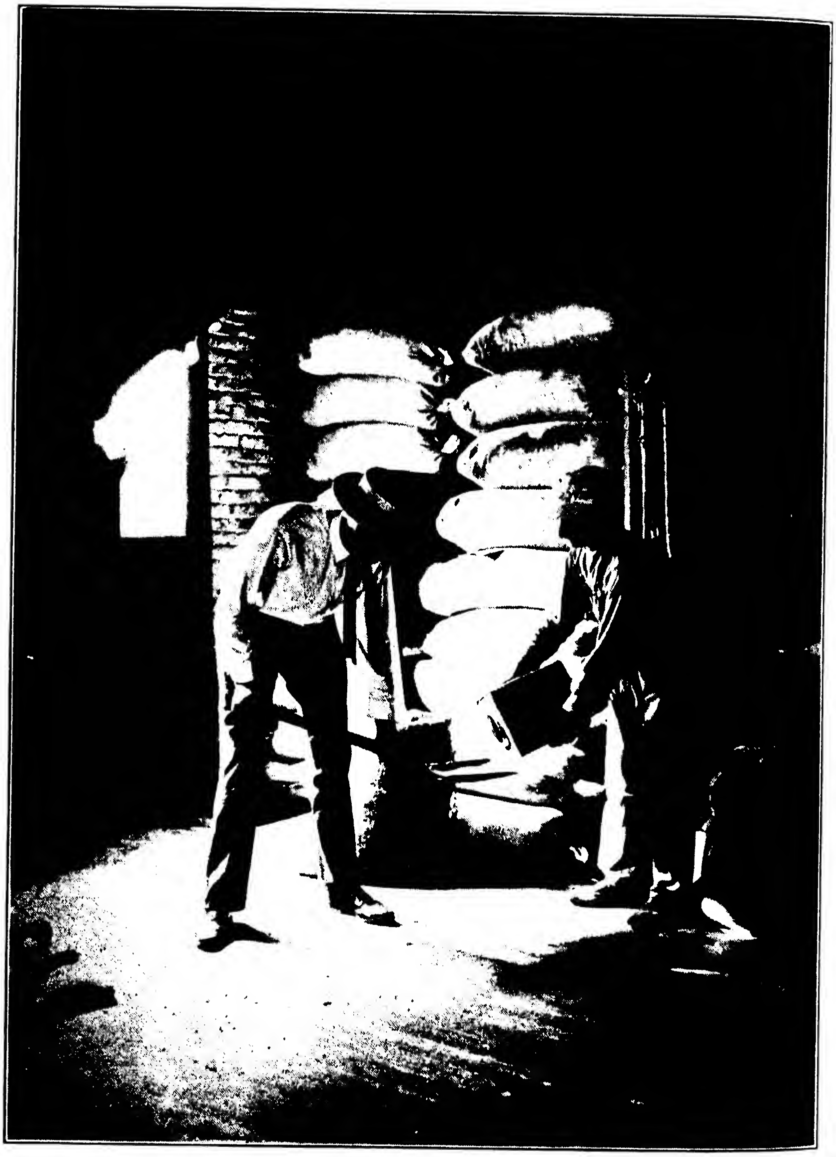


Fig. 10-3. Pouring Cyanogas on the Shovel Preparatory to Broadcasting the Material over the Floors.

Hydrocyanic acid is very slightly lighter than air. The ratio of the weight of HCN to that of air is 27:29. Its behavior would be very much the same as air under the same conditions, i.e. it would tend to rise when heated very much the same as air, or settle with cold air. The fact that it is slightly lighter than air indicates that eventually it will tend to rise. In a building most of the gas liberated on the lower floors eventually diffuses upward. Due to this reason, and to the fact that there is apt to be considerable leakage from the first floor because of the presence of doors and other openings, it was considered desirable to use a greater amount of material on the first floor than on the upper floors. Most of the gas rising through spouts would be taken from this floor in which the elevator boots are located. In some tests, therefore, the dosage was slightly cut on the upper floors and this amount applied to the first. As much as one pound was cut from the top floor dosage in some cases and added to the first floor, thus giving the first floor a dosage of about 3 pounds per 1000 cubic feet, while the top floor received only 1 pound per 1000 cubic feet. The other floors, including the basement, received the two pound dosage.

In other cases, there was considerable leakage from the top floor, particularly in wooden buildings, and the two pound dosage was therefore used on this floor.

Until further information on the movements of HCN in a mill are obtained, it would be best to consider each floor and room as a unit, and closed off from the rest of the mill, i.e. doors between floors and between rooms should be closed after the application of the fumigant in that particular floor or room. In the tests conducted, however, the extra labor of blocking the openings between floors where belting or machinery passed through was not practiced and this would seem to be unnecessary in most cases.

LENGTH OF EXPOSURE

Various periods of exposure were tested. The results as tabulated in the accompanying table (Table IV) indicate that a 36 hour period taken in conjunction with the dosage of 2 pounds per 1000 cu. ft. should give satisfactory results under most conditions.

TABLE IV
LENGTH OF EXPOSURE

Exp. No.	Length of Exposure (Hours)	Lbs. per 1000 cu. ft.	Results	Remarks
No. 18	22	1-1/2	Unsatisfactory	
No. 22	24	1-1/2	Unsatisfactory	
No. 24	24	1-1/2	Unsatisfactory	
No. 25	24	1-1/2	Unsatisfactory	
No. 3	24	1-1/2	Unsatisfactory	
No. 26	24	3-1/3	Satisfactory	
No. 21	36	1-3/8	Unsatisfactory	
No. 23	36	1-1/2	Satisfactory	
No. 19	36	2	Satisfactory	
No. 20	36	2	Satisfactory	
No. 27	36	2	Satisfactory	
No. 1	38	1	Unsatisfactory	
No. 7	38	2	Unsatisfactory	Building too open
No. 9	38	1	Unsatisfactory	
No. 15	38	2	Satisfactory	
No. 16	38	2	Satisfactory	
No. 12	39	1	Unsatisfactory	
No. 11	39	2	Satisfactory	
No. 13	39	1-1/2	Satisfactory	
No. 17	39	1-1/2	Satisfactory	
No. 10	39	1-1/2	Satisfactory	
No. 14	40	2-1/3	Satisfactory	
No. 6	41	1	Unsatisfactory	
No. 8	44-1/2	1-1/2	Satisfactory	
No. 5	48	1	Satisfactory	
No. 4	67	1	Satisfactory	

COMPARATIVE TEST WITH SODIUM CYANIDE

A comparative test, using Cyanogas Calcium Cyanide G-fumigant (Exp. No. 20) at a rate of 2 pounds per 1000 cubic feet and Sodium Cyanide at the rate of 1 pound per 1000 cubic feet was made. An exposure of 36 hours was given in both cases. The Cyanogas was used in the mill proper and the NaCN in the warehouse. The mill and warehouse were separated by a fire wall and double doors.

The two methods appeared to be about equally effective.

In the Cyanogas side, the control of the Mediterranean Flour Moth was satisfactory. None were found alive.

There was no infestation of this insect in the warehouse.

There was a heavy infestation of Tenebrio in the mill, but comparatively few in the warehouse. Hundreds of adults and a few larvae were found dead in various parts of the mill. Approximately 80 were found at the edge of one bin. Only one adult was found alive and that was in a partly stupefied

condition, being found in the basement underneath a log resting on the ground.

All cadelle larvae and adults seen were dead in both mill and warehouse. There was a heavy infestation of the Drug Store Beetle both in the mill proper and in the warehouse. These were very numerous on the floors, around sacks, and on the windows. All were dead except a very few between the window sills in both the mill and the warehouse. Many dead mice were found in both mill and warehouse, and 2 large rats were found dead in the mill.

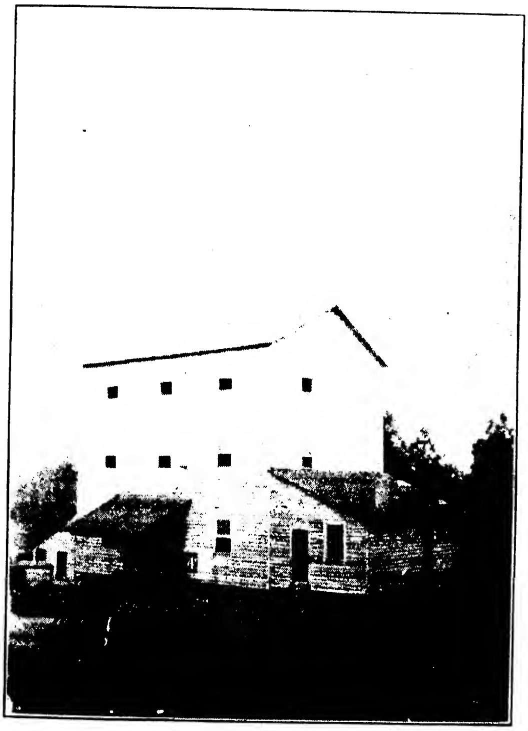


Fig. 11-3. A Small Loosely-constructed Wooden Mill. Such a Mill Requires a Great Deal of Sealing.

The Granary Weevil was quite numerous in both mill and warehouse. A number of the weevil were gathered from a representative square yard from both the mill and the warehouse, placed in pill boxes and examined the day following the fumigation and again four days following the fumigation to determine revival. The number alive and dead on the

Fig. 12-3. Rats and Mice Collected after a Fumigation. Cyanogas still present on the Floors.

latter date are as follows:

Cyanogas		Sodium Cyanide	
Dead	Alive	Dead	Alive
61	5	9	13

The more favorable results from the Cyanogas side were no doubt due to the fact that the weevil, in crawling through the Cyanogas scattered on the floors, remained in a strong concentration of gas for a longer period of time.

RECOMMENDATIONS

1. *Dosage*

   2 lbs. of Cyanogas G-fumigant per 1000 cu. ft. of space.

2. *Exposure*

   36 hours.

3. *Preparation*

   1. Calculate the cubical content of the mill by floors and separate rooms.

   2. MAKE THE BUILDING TIGHT by sealing with paper any cracks or open spaces in windows, doors, vents, panes of glass, eaves, etc., but arrange as many windows and doors as possible to be opened from the outside after the fumigation

is over. All outside doors, except the exit, should be sealed from the inside.

3. THOROLY CLEAN THE MILL before the fumigation. Do not leave more than one-half inch of flour in any part of the mill or machinery. Run the machinery empty for thirty minutes. Then use compressed air to blow out the conveyors, etc. Remove and burn all webbing, waste, and refuse flour in elevators, boots, packers, purifiers, conveyors, reels, etc. Whatever waste flour may be overlooked should be spread out on the floor and treated with Cyanogas during the spreading.

4. Previous to the fumigation, EVERY PART OF THE MILL MACHINERY SHOULD BE OPENED UP to allow direct access of the gas. Be sure that every slide door, conveyor top, cap and panel is opened. The elevator heads may—or may not—be removed. In the case of a heavy infestation of flour moth, it would be advisable to remove the heads and place them on the floors where they should be treated heavily with Cyanogas during the spreading.

4. *Conditions*

The temperature of the mill should be 65 F or over and the relative humidity over 40%. From 60-80% would be more ideal. Where the air in the mill is drier than 40%, the relative humidity may be increased by sprinkling water over the floors with a sprinkling can about 2 or 3 hours before the Cyanogas is to be applied. Make sure that there are no pools of water. Do not apply the Cyanogas until the water has thoroly evaporated. Never sprinkle water over Cyanogas or apply the Cyanogas where there are pools of water on the floors. Where sprinkling is not desirable, hang up about a dozen moist sacks to a floor about 3 hours previous to the fumigation and close the mill to hold the moisture.

Choose a calm, warm day. If a steady breeze is blowing and it is undesirable to postpone the fumigation, spread the Cyanogas more heavily on the windward side of the building.

5. *Application*

Altho the dosage is 2 pounds per 1000 cubic feet, in practice it has been found advisable to adjust this dosage on different floors of the mill to take care of the upward diffusion of the gas and different leakage conditions. In general, this is accomplished by using 1 pound per 1000 cubic feet on the top floor and about 3 pounds per 1000 cubic feet on the first floor. In other words, take one pound off the dosage of the top floor and add it to the first. The other floors, including the basement, should receive the 2 pound dosage. Where the top floor is leaky, due to its construction, it is advisable to use

the 2 pound dosage on this floor. If the elevator boots are located on any other floor than the first, use a few extra pounds on that floor.

Be sure the material is scattered in back of, around, and in under the mill machinery; around, in back of, and between piles of sacks; in the corners of the rooms; in and under the elevator boots; and under packers, and open spouts.

6. *Airing out After the Fumigation.*

First open up the doors and windows which may be reached from the outside, so that a current of air will be created to carry out the gas.

After airing out for an hour, at least 2 men each with a supply of Ammonium Carbonate may enter to open up other doors and windows. With the doors and windows still open, brush off the sacks, and sweep up the residue which may be disposed of by burying or throwing on the dump.

7. *Precautions*

1. Although the Cyanogas method of fumigating mills is the safest method of using hydrocyanic acid gas, one should not become careless and indifferent to the amount of gas which is being liberated.

2. Avoid breathing the gas as much as possible. From time to time, take deep breaths of fresh air as you go from floor to floor.

3. Always begin spreading in the end of the room furthest from the exit. So organize the application that no material is spread between a fellow-workman and the exit.

4. Avoid sprinkling Cyanogas where it will drop thru openings around belts, machinery, etc., to the floor below and thus be generating gas before you reach the next floor.

5. *Never go back into a room or back over the floor where Cyanogas has already been spread.*

6. Each workman must carry AMMONIUM CARBONATE to inhale if effects of the gas are noted. It is well, during the application, to take inhalations when moving from floor to floor.

CONCLUSIONS

The foregoing experiments show that where properly applied, Cyanogas Calcium Cyanide is effective as a fumigant for the control of insect and rodent pests in flour mills. The margin of safety to the operator and the ease and simplicity of handling make the method a much more satisfactory means of utilizing HCN for the fumigation of flour mills than any other method hitherto employed.

Issued February 15th, 1928.

SECTION 4

FUMIGATION—BURROWING ANIMALS

FUMIGATION — BURROWING ANIMALS

Many species of rodents and other animals which make distinct burrows in the ground have been successfully controlled by the use of Cyanogas Calcium Cyanide. Naturally, in dealing with such a wide range of pests, the methods of application will vary considerably. In general these fall into the following groupings.

FIRST: By merely placing the material well down in the entrance of the burrow.

a.—Burrows closed after treatment.

b.—Burrows left open after treatment.

This method is particularly adapted to the control of animals with few entrances to their burrow such as: Ground Squirrels, *Citellus spp.;* Woodchucks, *Arctomys monax;* Prairie Dogs, *Cynomys sp.;* Land Crabs, *Cardiosoma sp.;* Crayfish, *Cambarus spp.;* Land Turtles, *Gopherus polyphemus;* and Ants.

SECOND: By blowing Cyanogas "A" Dust throughout the system of burrows.

The method is adapted for the economic treatment of animals which have an extensive system of burrows and many entrances such as: Rabbits; Rats; Leaf-cutting Ants, *Atta sp.;* and Termites.

THIRD: The application of Cyanogas by means of artificial openings made into the burrow or nest.

This method is particularly useful for those animals which have a closed or nearly closed system of burrows such as: Moles, *Scalops aquaticus;* Golden Mole, *Chrysochloris sp.;* Pocket Gopher, *Geomys spp.;* Taltuza, *Hetergeomys torridus;* Mound-building Harvester Ants, *Pogonomyrmex sp.;* and Mound-building Termites.

Some of the earliest experiments with Cyanogas Calcium Cyanide as a rodenticide were performed by Prof. G. E. Sanders, Department of Agriculture, Ottawa, Canada. The account of this work against the Richardson Ground Squirrel, known as the "Gopher" or "Flicker-tail" in Canada, appeared in the Agricultural Gazette of Canada, Vol. VIII, No. 6, November, 1921, page 628, and is reproduced below :

GOPHER CONTROL BY MEANS OF CALCIUM CYANIDE

BY G. E. SANDERS, ENTOMOLOGIST IN CHARGE INSECTICIDE INVESTIGATIONS, ENTOMOLOGICAL BRANCH

IN 1920, Mr. A. Kelsall, of the Entomological Branch, tested chlorine gas for the control of gophers at Carlyle, Saskachewan. It was found by him that gophers were very effectively controlled by injecting about one-tenth of a pound of chlorine gas, liberated from cylinders of liquid chlorine, into each gopher burrow. A brief account of this work appeared in the November issue, 1920, of the *Agricultural Gazette of Canada*.

In 1921, the writer continued these experiments and in addition tested a number of other chemicals. Among these, a comparatively new cyanide, in peculiar physical form, manufactured in electric furnaces at Niagara Falls, Ontario, showed great promise.[1] The compound contained approximately 50 per cent calcium cyanide and is marketed in small flakes, grayish-black in colour, about 1/32 of an inch in thickness and about ¼ to ½ of an inch in diameter. It is not nearly so deliquescent as sodium or potassium cyanides. Its physical form, as well as its chemical constitution, assist in its comparatively rapid decomposition when placed in contact with damp earth, or less rapidly on exposure to air, the products being prussic acid gas and hydrated lime.

The first promising experiment with this material consisted in treating half a dozen burrows. Following this, 13 burrow openings were closed and 12 of these that were opened the next day were treated, about 1½ ounces of the mixture finely ground being placed down each burrow. Six hours after none of the twelve treated burrows were opened although gophers had started to dig into all of them from the outside.

Examination twenty-four hours later showed that only two of the 12 treated burrows had been opened.

The next experiment, on July 11, consisted in treating an area of approximately two and one-half acres containing 62 gopher burrows. In this experiment the flake form was used. The material was carried about in an open bucket and dipped out with a long handled iron spoon and placed as far down the burrow as was possible. The spoon held approximately 2½ ounces and one spoonful was used in each burrow. A handful of weeds was placed in the entrance of the burrow and the iron spoon used to cover the weeds with earth. Placing the weeds in the entrance prevented the earth from covering the cyanide. Forty-eight hours later, not a single burrow of the 62 closed had been opened. Gophers were particularly active in the immediate area, the land being very light, sandy and dry.

The next experiment consisted in treating in the same manner as the last, 69 burrows in heavier land. Twenty-four hours after treatment, two out of the 69 treated burrows had been opened.

In another experiment a jar was measured and the amount of the calcium cyanide compound calculated to give the same concentration of gas as would obtain if 2½ ounces were placed in a burrow 40 feet long. A little earth was placed in the bottom of the jar and the cyanide thrown in on top of it. A live gopher was then introduced and the jar closed. The gopher immediately showed the effect of the cyanide; in a short time its muscles became rigid and the neck curved backwards until the head almost touched the back. The body became limp when the gopher died. Fifteen live gophers were available and all were killed in this jar. It was found that five seconds exposure to the gas was sufficient to cause death. This explained the excellent results we had obtained in the field.

We have not as yet definite data as to the cost of the cyanide treatment but it is thought that it will approximate that of strychnine poisoned grain.

The cyanide used, as above mentioned, is for the most part calcium cyanide or the lime salt of prussic acid. It must, therefore, be regarded as a dangerous poison and one which should not be stored carelessly about buildings. It should, in fact, be handled with extreme care such as are arsenic, strychnine and other poisons used in agriculture with which the public are familiar.

With strychnine-poisoned grain, there is danger in storing it in sacks in which it is always shipped, and in the field in spite of repeated instructions to put it down the burrow, the farmers almost invariably scatter it on the surface about the entrance of the burrow, thus endangering both wild and domestic animal life.

Calcium cyanide has the advantage of being as effective at one season as at another while poisoned grain is most effective for a short time only in the spring before the grasses start, so that even though it may not compete economically with poisoned grain for spring work, it should be a valuable adjunct for summer control.

RABBITS

Early experimental work on the use of Cyanogas Calcium Cyanide for the destruction of rabbits in New South Wales, Australia, was carried out by Mr. Max Henry. Flakes were used in this series of experiments as was the case in Sanders' work. Reports on these experiments are reproduced from Agricultural Gazette of New South Wales, Vol. XXXIV, pt. 7, July, 1923, page 485.

Fig. 1-4.—Application of Cyanogas "A" Dust to Rabbit Warren with Duster. Note Dust Emerging from Opening at a Distance from Point of Application. New South Wales, Australia.

Dust was introduced into Australia in 1923 for the first time by Professor H. J. Quayle of the University of California, and the report of a second series of experiments was

Fig. 2-4.—Pile of Dead Rabbits Dug from Treated Warren.

published by Mr. Max Henry in the Agricultural Gazette of New South Wales, Vol. XXXV, pt. 2, February, 1924, page 125 (Figs 1-4, 2-4.).

Dr. R. J. Tillyard of the Cawthron Institute was the first scientific worker in New Zealand to realize the value of Cyanogas Calcium Cyanide for the destruction of rabbits. Unfortunately his experiments were delayed for about a year, due to illness, with the consequence that his paper on this subject did not reach the press before 1925. The account of his experiments is taken from the New Zealand Farmer, Auckland, March 2, 1925. These three papers on the control of rabbits with Cyanogas Calcium Cyanide are reproduced below:

The Destruction of Rabbits with Calcium Cyanide.*

MAX HENRY, M.R.C.V.S., B.V.Sc., Government Veterinary Surgeon.

THE calcium cyanide used in the experiments described hereunder is a commercial preparation in the form of thin brownish flakes, that give off a strong odour of hydrocyanic acid gas.

It is claimed by the manufacturers that on exposure to the air there is left, after the hydrocyanic acid gas has been given off, only a harmless residue composed of hydrated lime, graphitic carbon, and salt. The length of time during which this material will continue to give off hydrocyanic acid gas is being tested, but it is undoubtedly somewhat lengthy, which is a factor of importance in considering the value of calcium cyanide for the purpose. It has been used in Canada in the destruction of gophers, the small burrowing rodents which in many parts of North America constitute a very serious and destructive pest. In the experiments detailed below the directions of the manufacturers were followed, due allowance being made for the difference in local conditions and in the habits of the rabbit and the gopher. Although the gas given off is lighter than air, it was claimed by the manufacturers that it would diffuse downwards through the burrow, even if only placed on the ground above the openings and covered with a tarpaulin. That method was not employed, being considered unsuitable to our conditions and involving a possibility of risk to live stock, but the gas was found to possess high diffusive power and to penetrate widely in the burrow.

A burrow apparently suitable for experimental work having been selected, from 1½ to 2 oz. of calcium cyanide was introduced into each opening with the aid of a wooden spoon about 15 inches long. The openings were then carefully blocked with dry cow-dung, leaves, or wood, to prevent earth falling in and covering the poison, and this protection was in turn covered with earth, to prevent, or at least check, the outflow of air and gas. Experience indicated that it is desirable to give some little attention to this blocking of the openings of the burrow, not only to ensure the maximum concentration of the gas inside, but to prevent opening up of the burrow from the outside. Quite a number of rabbits were found dead just inside, as though they had attempted to escape, but, owing to careful blocking, were unable to do so before being overcome by the effects of the gas. The burrows were opened up at different times, varying from one hour twenty minutes to ninety-six hours, subsequent to the introduction of the cyanide. There was evidence that the shorter periods were not sufficient to allow the gas to take effect

* Constituting a preliminary report of experiments carried out under instruction from the Experiments Supervision Committee of the Department of Agriculture.

under the conditions existing at the time and with the dosage employed, and for further work it is suggested that a minimum of twenty four hours be considered as required to ensure the destruction of all inhabitants of the burrow.

The details of the experiments carried out so far are stated in the following paragraphs :—

The First Series of Experiments.

These experiments were carried out in rather hard, very dry, decomposing granite soils on a hillside They were disappointing, as it was evident after completion that very few rabbits were present, but they were useful educationally.

No. 1.—A small burrow with eight openings. Approximately 12 oz. of calcium cyanide was introduced into the burrow, 1½ oz. being placed in each opening at 9.50 a.m The burrow was opened up at 11.15 a.m. The odour of hydrocyanic acid gas was very marked, not only in the burrow but in the air surrounding it, when being dug out. Two living rabbits were found.

No. 2.—A burrow similar to No 1, but larger, the measurements between extreme openings being 36 x 27 feet. The cyanide was put in at 10.10 a.m., 18 oz. being used. It was opened up between 11.30 a.m. and 2.50 p.m. The gas was well diffused, even at a depth of 3 feet. At 2.45 p.m. some of the calcium cyanide which had been put in was examined, and found to be giving off comparatively little odour. There were no rabbits in this burrow.

No. 3.—A small burrow similar to No. 2. 15 x 18 feet; 15 oz. put in at 10.30 a.m. Dug out 3.30 p.m. Diffusion of gas as in No. 2. No rabbits,

No. 4.—Burrow similar to No. 3, 15 x 15 feet; 15 oz. put in at 10.45 a.m. Opened up 3 p.m. One rabbit found alive 3 feet below ground and about 5 feet from nearest opening. Gas fairly well diffused.

No. 5.—Burrow same as No. 4; 24 x 24 feet; 24 oz. cyanide put in at 11 a.m.; dug out 4 p.m. No rabbits.

These experiments showed that the gas did diffuse to some extent at least, but suggested that possibly the burrows were not left closed for a sufficient length of time.

The toxicity of the gas given off by the calcium cyanide was demonstrated on one of the living rabbits caught. Its head was placed in the tin containing the cyanide, and it died in less than five seconds.

Second Series.

No. 6.—A small burrow on a river flat; 9 oz. cyanide put in at 10.30 a.m.; opened at 2 p.m. Result nil.

No. 7.—A burrow beside a creek, fairly large, and with many openings: soil slightly moist; 15 oz. cyanide put in at 10.45 a.m.; opened up at 3 p.m. Twelve dead and four living rabbits were obtained from this burrow.

The dead rabbits had evidently been destroyed by the gas, as they were only just dead and showed no evidence of any disease. No poisoning had been carried out recently. This burrow, besides being moist, was on a slight rise,

both factors which might have had an influence on the result. A little horse-dung was burnt in one of the openings and smoke driven through to indicate whether any leakage was occurring.

Third Series.

No. 8.—Superficial area 27 x 18 feet; in dry country on hillside; 12 oz. cyanide introduced at 11.30 a.m. 5th March. Dug out partly at 5 p.m., 5th March, and finished 9 a.m., 6th March. Three dead rabbits found. Gas evident on both days.

No. 9.—Superficial area 12 x 12 paces; dry on top, a little moisture below; on hillside in decomposing granite soils; 9 oz. cyanide put in at noon, 5th March. Dug out 10 a.m., 6th March. Four dead rabbits.

No. 10.—A burrow with one opening only; on edge of river flat; ground dry and hard; 6 oz. cyanide put in at 12.10 p.m., 5th March. Dug out 11 a.m., 6th March. Five dead and one living rabbit found. The living rabbit was 23 feet from the opening. The sexes of the rabbits were three male and three female.

No. 11.—A big sandy warren on river flat; superficial area 42 x 24 feet. Two gallons of water were used to moisten the openings of burrows to hasten evolution of gas. Cyanide (27 oz.) put in at 2.30 and 3 p.m., 5th March. Dug out from 12 noon to 5.45 p.m., 6th March, and finished on 7th March. Twenty-four dead rabbits and one living one were found. The ground was very dry and the gas still evident on completion of the work at 12.30 on 7th March.

No. 12.—A single opening burrow on hillside; dry. One gallon water used to provide moisture. Cyanide (5 oz.) put in 3.40 p.m., 5th March. Opened up 7th March at 2 p.m. Three dead rabbits found.

No. 13.—An old burrow on hillside; very dry. Three gallons of water used and 9 oz. cyanide. Put in 4.15 p.m., 5th March, and dug out 8th March. Four dead rabbits found.

Fourth Series.

No. 14.—Burrow on hillside; a reddish clay soil; very dry; 7 oz. cyanide placed in burrow at 12.20 p.m., 16th April, and dug out 18th April, eight rabbits obtained, five dead and three living. The presence of gas was not marked to the sense of smell.

No. 15.—Similar to No. 14; 3 oz. cyanide placed in burrow at 12.40 p.m., 16th April. Dug out 2 p.m., 18th April. Four rabbits, all dead.

No. 16.—Similar to No. 14, but very extensive; 14 oz. cyanide put in at 1 p.m., 16th April. Dug out 20th April. One rabbit dead. Work not completed.

No. 17.—Cyanide (3 oz.) put in 2.30 p.m., 16th April.

No. 18.—Large burrow, 30 oz. used.

No. 19.—Small burrow on flat, 3 oz. used.

No. 20.—Single opening burrow on flat.

Owing to lack of time, burrows Nos. 17, 18, 19, and 20 were not dug out, but four days after the cyanide had been put in they still remained unopened, so that the death of the rabbits in them is very probable. All were active burrows.

The material used in this series of experiments was from a tin that had been opened up some weeks, and the gas in the burrows was not so noticeable as in the previous three series.

As regards some of the living rabbits found, it is not considered that they could have survived, since they were at dead-ends with the gas-producing material and dead rabbits between them and any available opening. It is considered that the cause of death in all instances was the inhalation of hydrocyanic acid gas, there being no evidence or suspicion of any other cause operating.

In only two instances were the burrows entered from without after treatment and in no case were they opened up from inside.

Conclusions.

These results are considered encouraging and make further trials desirable. The advantages of this method of rabbit destruction are:—

(1) Only a small amount of labour is required.

(2) Providing the material is used as directed, there is absolute freedom from danger to live stock.

(3) As the burrows in which the rabbits are killed are closed up, blow-flies cannot breed in them.

(4) No expensive plant or machinery is required.

(5) There is no danger of destroying bird life.

(6) Poisoning can be carried out at any time and in any season.

The disadvantages are:—

(1) The rabbits, being left in the burrows, cannot be used as a commercial asset.

(2) The method cannot be relied on to eradicate rabbits.

(3) Wire netting would still be a necessity.

(4) The material used is very poisonous.

The actual destruction of the rabbits is due to the giving off of hydrocyanic acid gas by calcium cyanide. This gas is one of the most poisonous known and is rapidly fatal if inhaled in sufficient quantity. It is therefore necessary to issue a warning, which indeed is stressed by the manufacturers, that great care should be exercised that the tins containing the material are kept tightly shut when not in use, that they should not be kept in rooms used as sleeping and living rooms and that they should be put absolutely out of the reach of children.

The well founded objections to the use of potassium cyanide—that is, the danger to live stock, etc.—as a means of destroying rabbits do not apply to this material, so it would not be possible to use it in the same way.

It is proposed to carry the experiments further.

4-10

The use of Calcium Cyanide as an Agent in the Destruction of Rabbits.

MAX HENRY, M.R.C.V.S., B.V.Sc.

FOLLOWING on experiments previously reported,* it was decided to carry out experiments on a larger scale, using both the flake and the powder forms of the material known as "calcium cyanide."

Two paddocks were selected on the bank of the Cudgegong River, one of about 70 acres, and the other somewhat larger. Both paddocks were fairly clear of timber, and were fairly well netted, but some silting up had occurred, and some of the warrens evidently connected up with warrens outside the paddock. The soil was half black alluvial, and the balance rising red country of a sandy nature. Over much of the paddocks was a heavy growth of herbage, which made the locating of the openings difficult. Evidently the paddocks had been very heavily infested in the past season, and at the time of operations many warrens were just being opened up.

Dealing with the material in flake form first, it may be stated that it was found that instead of 1 oz. of material being required to each opening of a burrow, equally satisfactory results were obtained with ½ oz. per opening. Two burrows treated in this way were opened up, and though unfortunately they only contained two rabbits each, all four animals were dead.

In all eighty-seven burrows were treated with flake, requiring the stopping of 1,391 openings. With the powder, 162 warrens were treated, requiring the stopping of 2,507 openings. Of these, nine burrows were dug out, and although again the number of rabbits found was low (eleven being the greatest number in any one burrow) all were dead.

To deal with the warren mentioned above, in which eleven dead were found, took approximately 4 oz. of material, and blowing was continued for 2½ minutes.

A week after the work was completed, the Inspector of Stock and the Rabbit Inspector revisited the area, and found that nearly every warren had been re-opened, in practically every case from the outside, so far as could be determined. This applied to both "flake" and "dust" paddocks. Some untreated warrens were found. Judging from the odour emanating from the burrows and the presence of flies, it was evident that many dead rabbits were enclosed.

The results obtained were considered to promise well for this method of rabbit destruction.

* *Agricultural Gazette*, July, 1923, page 485.

As evidence of the occupation of the warrens and the killing effect of the treatment, nine warrens were dug out with the object of arriving at the toxic effect of the material. Six of these were in the high country, and three in the black alluvial soil.

Among the former, one warren with six openings, using 4½ oz. of calcium cyanide dust, taking 2 minutes to apply, was dug next morning, and contained only one rabbit about the centre of the main run through; this was dead.

Another warren with twenty-three openings, using 5 oz. of dust on the same afternoon, closed in 5 minutes, was dug out next morning, and held only three rabbits, all dead. One of these was in a dead end, and two were in the lower levels in the centre of the warren.

Another warren with eleven openings, using approximately from 5 to 6 oz. of dust (not weighed), taking 3½ minutes to treat, was dug out next morning; it held one rabbit at the intersection of two main runs well in the warren. This was dead.

A fourth warren was treated at midday with approximately 5 oz. of dust. No time for treatment was taken in this instance. Digging was commenced on this 1½ hours after treating, taking four men 3¾ hours. It contained only one rabbit (dead), 3 feet from the surface on a side run.

The other two test warrens dug out in this higher portion had no rabbits, although they showed clear evidence of having been recently occupied. It can be accepted that the rabbits were visiting these warrens each evening from their living quarters in the lower warrens preparatory to occupation.

Dealing with the three test warrens in the black alluvial country, one appeared to be a deep and long-established warren. It had thirty-four openings; was treated for 15 minutes at 9·45 a.m., using 6 oz. of calcium cyanide dust. Digging with four men was started at 11 a.m. the same day, and the digging finished at 2 p.m. the following day—ten hours' work. This warren contained nine rabbits, distributed at various levels, apparently dying where they rested; the deepest one found was at 5 feet from the surface, which was the maximum depth. All were dead.

Another warren with six openings—very large ones, taking 2½ minutes to treat—used approximately 4 oz. of calcium cyanide. The work of digging out was commenced at 10·30 a.m., 50 minutes after treatment, and finished at 3·30 p.m. This held eleven rabbits all dead. Of these four were suckers, found bunched in a dead end, well covered with a fur nest. The balance were well distributed.

The other test warren in the black alluvial soil when dug out contained no rabbits, although there was clear evidence of it having been worked.

A Few General Observations.

In no case was there a live rabbit. No burrows were opened from the inside after treatment, except in one instance. This was a vertical opening, and it looked as if it might have fallen in from the contraction due to the drying out of the soil which was thrown on top of it.

Many openings were covered and invisible owing to the heavy thistle and crowfoot growth, and were only located with the rising dust cloud. The calcium cyanide dust was successful in clearly indicating where these small listening and pop holes were situated at any distance. The dust travelled with considerable speed with the assistance of the blower from one end of the largest warren to the other, one of which had eighty openings, and many others forty and fifty. The average number of openings per warren in the entire paddock was between fourteen and fifteen. Warrens with a few openings on the river bank at times took longer (evidently on account of their depth) to send the dust through than at times did more shallow ones with a greater number of openings on the higher country. From the location of the dead rabbits in the warrens it would appear that calcium cyanide kills very quickly.

It was found desirable to economise the material, using from two to five charge strokes according to the size of the warren, then shutting off and blowing as near as possible air only, and by this means distributing the charge.

With the machine in use it was not possible to shut off completely so as to prevent a certain amount of dust going through at every stroke, and it is thought that to give the most economical results it will be necessary to adapt the machine to give the minimum amount of material, and afterwards practically to pump air for the distribution of the dust already driven into the burrow by the first few strokes.

Although calcium cyanide is of a highly poisonous nature, and immediately gives off gas on exposure to the air, it had no effect whatever on the operator, or on the men closing the openings or digging out, even when the warren was opened up shortly after application.

Warrens in the alluvial country on the average were deeper, with fewer openings, and requiring more material. It was found economical in treating large warrens to blow into more than one opening. From the dead rabbits found in the warrens treated this way, it was evident that the dust had penetrated right through.

Subsequent Report from the Stock Inspector.

A week after the work was completed the Inspector of Stock and the Rabbit Inspector visited the area, and the former submitted the following report:—

"We found that almost without exception at least one opening in every warren treated was re-opened. In many cases the number opened up was greater—two, three, four, and so on—and the greatest number of re-openings counted to one warren was twenty. These conditions applied to both the 'dust' and 'flake' paddocks With the exception of two or three doubtful, all the openings appeared to have been opened up from the outside. The doubtful ones gave the impression that possibly they may have been scratched out from within.

"In the eastern corner of the 'dust' paddock, we discovered one large 'working warren' with fifteen openings, which had been missed in the

experiments, and we also discovered a number of other openings throughout the two paddocks that had been missed, being hidden by thistles and thick herbage. The large warren mentioned appeared to have a fair number of rabbits in it, and possibly it was the rabbits in this and other warrens that re-opened the majority of the treated warrens.

"We made a careful and close inspection of many of the re-openings in the treated burrows, and from the number of blow-flies flying in and out of these openings, and by the smell emanating from within, it was very evident that many of the rabbits that were enclosed were dead before the burrows were re-opened.

"These conditions apply to both the burrows treated by the flakes and those treated by the dust."

Later Confirmation.

Since the above experiments, further work has been carried out at Mudgee, and in the north-west, and the results obtained confirm the opinion previously formed that the use of this material offers considerable promise for the destruction of rabbits.

It would appear probable that the use of dust or powder with a blowing machine would economise material and time, but two men are required, and a machine must be purchased. The use of flakes requires more material, though evidently not half as much as was used at first, and one man can carry out his own work, and going steadily could cope with a number of burrows. Where large areas have to be cleared up and labour is available the powder is to be preferred, while for men on small holdings who do their own work—and that at irregular intervals and times, fitting it in with other farm work—the flakes would probably be cheaper in the long run.

So far as effectiveness goes, there appears to be no appreciable difference. The gas would be given off quicker by the powder, but would continue to be given off for a longer period by the flakes.

As regards the rapidity of the gas as a killing agent, it may be mentioned that a rabbit enclosed in a box with a content of 12 cubic feet, was killed in four minutes by one thirty-second of an ounce of powder blown in through a small opening.

The work confirmed the previous good opinion formed as to the penetrating power of the gas.

Destruction of Rabbits by Calcium Cyanide Dust.

By R. J. TILLYARD, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), F.N.Z. Inst., F.L.S., F.E.S., C.M.Z.S., Chief of the Biological Department, Cawthron Institute, Nelson.

While attending the Pan-Pacific Congress in Sydney a year ago, the writer met Professor Quayle, of the University of California, and discussed with him the problem of rabbit destruction. Professor Quayle is the inventor of a new process of rabbit destruction by means of Calcium Cyanide Dust, and was able to give the writer first-hand information as to his experiments in Australia. Later on, additional information was given by Mr. Max Henry, chief of the live stock division in the Department of Agriculture, New South Wales. Being convinced of the great value of this new method, arrangements were at once entered into with the American Cyanamid Company of New York (the manufacturers of the cyanide dust and the machines with which to apply it), and one of the machines, together with 200lb of cyanide dust, was imported from New York for the purpose of testing the method in New Zealand.

A SMALL RUN, SHOWING HOW AN OBSERVER MAY TRACE THE CONNECTED EXITS.

Two field tests have been carried out by the staff of the biological department of the Cawthron Institute, the work in each case being in charge of Mr. E. S. Gourlay, second assistant entomologist. The first test took place at Rabbit Island, by request of the Waimea County Council. This test was not regarded as conclusive, because the Council's workmen had been busy during the previous fortnight poisoning with strychnine, and, as a result, a large number of rabbits had already been destroyed. Its chief value was to demonstrate the ease and safety with which the machine and chemical can be handled. The second test was made in response to a request from the Forestry Department, and consisted in the treatment of a rabbit-infested area near Seddon, the object being to destroy the rabbits before planting the area with young trees. The details of this test are given in Mr Gourlay's report, see page 5.

RABBITS IN SITU.

As uncovered after the warren had been closed up for 24 hours.

The result of this second test was highly satisfactory, and so clearly corroborates the conclusions arrived at by those who have been testing the method in the various Australian States that the writer now has no hesitation in most strongly recommending the method as by far the best, cheapest, and most efficacious remedy yet discovered for the destruction of rabbits over large areas. With a view to making the method clear to farmers throughout the Dominion, the following points are now set out:—

Nature of the Chemical Used.

The chemical used is Calcium Cyanide, prepared in the form of an extremely fine dust or powder, as fine as flour. The chemical itself can be handled without danger, providing that it is kept dry; its great killing power lies in the fact that, when exposed to moisture, a chemical reaction takes place which results in the production of the highly poisonous hydrocyanic acid gas. The chemical is supplied in special retainers containing 25lb each; these can be opened and the dust weighed out and repacked into smaller tins if so desired. If the dust is sniffed in accidentally through the nose, a severe headache would be the result; but with a little care this can easily be avoided. The dust should not be handled in a moist atmosphere or during rain without very great care being exercised.

Type of Machine Used.

The type of machine used for blowing the dust into the burrows is known as the "American Beauty Dust Sprayer," as supplied by the American Cyanamid Co. of New York, and their Australian agents, Messrs. Buzacott and Co., Ltd., Market Street, Sydney. The machine is illustrated in the picture on p. 4, which shows a man with it strapped in position on his back, and with the handle depressed at the end of the stroke by which the dust is pumped out in the form of a whitish cloud. These machines are of very neat and simple construction, easy to keep clean, and carry enough dust (about 10lb) for a full day's work in the warrens. Inside the cylinder there is a feeding arrangement which regulates the supply of dust to the blowing tube, the average number of puffs to the ounce being about twenty. This gives 3200 puffs for a day's work, using 10lb of cyanide.

Method of Use.

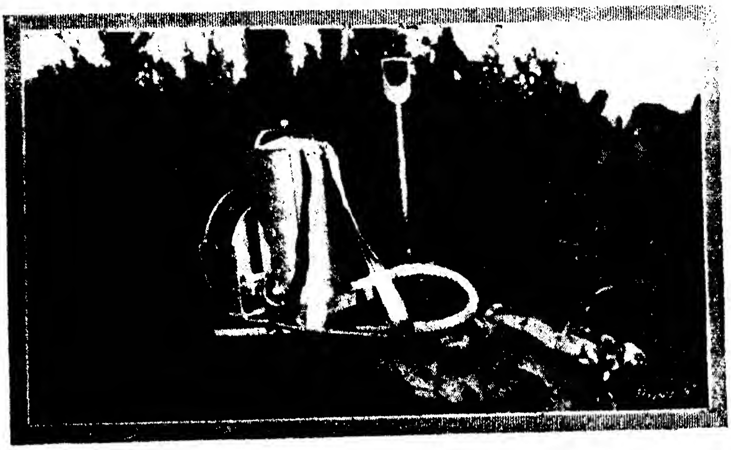
In order to get the best results, certain simple rules have to be followed. These can easily be mastered by anybody, since they are the dictates of common sense, and require no special scientific knowledge. They may be summarised as follows:—

A.—A preliminary survey of the ground to be worked should be undertaken first. The main object of this is to get a good idea of the type of warrens to be treated, and more especially to mark those places where two, three, or four channels run into a single opening near the surface. In such cases, it is clear that the treatment of only a single channel would be useless; therefore the best practice is to dig back with a spade so as to expose each channel. The safe rule in dealing with this type of opening is to see that each channel shows a dust cloud issuing from it before being closed up.

B.—Pop holes (vertical holes leading into a channel) should not be filled with soil, as this tends to block the passage of the dust along the channel below. The best plan is to cover each pop hole with a clod or tuft of grass, and then place the soil above that, ramming it down after the dust has been blown in.

C.—Carrying on the blowing operations from the windward side of the warren, so as to prevent the breeze blowing the dust back along the channels towards the operator.

D.—In treating any section of a warren the method is to insert the nozzle about three or four inches only, not more, and then pump the dust in. Continue to puff until a good cloud of dust is either seen to rise from other exits or begins to come back out of the hole it is pumped into. In the first case, it is clear that a branched warren is being treated, and an assistant with a shovel should cover in each opening with earth as soon as a good cloud of dust is seen rising from it, taking care to mark each place so covered in with a stick or twig stuck into the ground. In the second case it is clear that a blind warren is being treated, and all that is necessary is to close the single hole.



A CLOSE VIEW OF THE MACHINE, INDICATING ITS CONSTRUCTION. Victims in the foreground.

If the warren treated shows a considerable number of exits, it is advisable to treat it by blowing through several of them. The rule to follow in this case is, after having treated one opening, to select for next treatment that opening out of which the cloud of dust is longest in appearing. By blowing into such an opening it often happens that a new reticulation is discovered, which could not have been reached from the original hole treated. Always cover up the treated hole before leaving the warren.

E.—Leave each warren treated covered up for at least 24 hours, so as to allow for rabbits, coming up from the deeper levels at feeding time, to get into the gas zone. Experiments show that, if the burrows are opened too soon, some of the rabbits may be able to escape by rushing out through the gas zone too quickly to get poisoned.

Effect of the Cyanide Dust in the Burrows.

When the dust is blown into the burrows, it travels along the channel fairly quickly, leaving a fine coating on the walls, and finally, finding a new outlet, it emerges as a dust cloud. Owing to the slight dampness of the walls of the burrow, hydrocyanic acid gas is given off gradually, and spreads through the burrows, forming a gas zone. Any rabbit which has to pass through this gas zone and breathes in it will die of prussic acid poisoning within a few minutes. Many of the rabbits, however, will remain in the lower levels of the burrow until driven to emerge by hunger; thus, if the burrows are opened too soon and the gas allowed to escape, some of the rabbits will not be destroyed. Sometimes rabbits are resting in the channels along which the gas is puffed; these breathe the dust into their lungs direct, and die very quickly

Results of the Seddon Experiment.

Two hundred warrens were treated in the experiment carried out near Seddon. The largest number of exits to one warren was twenty-five, with a calculated area of reticulation of about ninety yards, for which eight ounces of dust were required.

No warrens were dug out earlier than twenty-four hours after treatment; except in the case of one warren, in which owing to great depth, the digging could

not be carried any distance, dead rabbits were found in every warren opened. In one case only was a rabbit found dead in the act of attempting to escape by scratching at the closed exit; in one other case only did a rabbit run out from a burrow before the exit was closed, and this rabbit succumbed in two minutes, after running only ten yards, showing all the symptoms of prussic acid poisoning. In all the other cases the dead rabbits were found in the burrows, where they had collapsed from the gas.

READY FOR THE DAY'S WORK.

Warrens may be treated with the operator standing erect by affixing an extra tube. The dust is clearly shown.

The report emphasises that care must be taken in digging out the burrows, as the pungent odour of the hydrocyanic gas is noticeable even three days after treatment, and incautious breathing of it will cause a severe headache.

However, except in the case of experimental trials such as the one at Seddon, the burrows need not be opened to see the results; all that is necessary is to leave them closed up for good, and then to note the decrease in the numbers of rabbits seen and the amount of damage done by them. Probably a certain number will escape destruction after the first course of treatment, and these will in time open up new burrows, which should be again treated when the necessity for checking the rabbits becomes clear.

Area Capable of Treatment per Diem.

In moderately infested country, as at Seddon, an area of from five to eight acres per diem was treated; doubtless with increased skill in the use of the machine this amount could be considerably increased. Ten pounds of cyanide should be allowed for a day's work (the actual amount used at Seddon was nine and a-quarter per diem, but the time was near mid-winter, and the day consequently a short one.)

Some Australian operators report being able to treat considerably more acreage per diem than this, but the class of country is perhaps easier to work.

Cost of Treatment per Acre.

The Calcium Cyanide Dust is being sold in Australia at the following prices:

25lb containers	35/-
10lb containers	16/-
5lb containers	8/6

The price of the dust-blowing machine in Australia is £8/10/-. The Agents for New Zealand are Messrs. Wright, Stephenson, Ltd., of Wellington. Prices should not differ much from those given for Australia.

On the basis of the Seddon experiment, the average amount of cyanide used to the acre would be 1¼lb, so that the cost of treating 100 acres works out as follows:—

100 acres at 1¼lb per acre of cyanide dust equals 125lb dust.

125lb dust at 35/- per 25lb equals £8/15/-.

Cost of dust treatment, excluding labour, 1/9 per acre.

Recent reports from Australia indicate that treatment of large areas of rabbit-infested country can be successfully carried on at a lower cost than this; an area of 5000 acres near Leeton, N.S.W., has recently been cleared at a cost of 6d per acre, and a contract for clearing another 4500 acres further north has been let to a firm at 9d. per acre. Of course, the cost per acre depends on the density of the infestation and the nature of the country, but the above figures are quoted as a guide to what may be expected.

Advantages of the Method.

The new method offers many obvious advantages. In the first place, the machine is light and easily carried on the back; it is easily filled and operated, and no skilled knowledge is required in using it. In the second place, the

chemical used is not poisonous to handle, and is quite harmless as long as it is kept tightly closed down and away from moisture. Thirdly, the chemical used is not inflammable, as is the case with carbon bisulphide. Fourthly, and this is one of the most important points in using the cyanide method, there is no danger of poisoning valuable animals other than rabbits; only animals actually in the burrows will get killed. Fifthly, there is no special preparation of poison baits required, as in the use of strychnine.

In Australia one of the most disastrous results which followed the use of the poison cart was the wanton destruction of native birds; another was the great increase in blowflies due to the larvae breeding in the dead carcases lying about. With the new method, the birds are not exposed to any risk, and the dead rabbits do not lie about for blowflies to breed in.

simplest, and, at the same time, most scientific way of destroying rabbits has at last been found.

[Copy of report by Mr. E. S. Gourlay on the work done near Seddon, July, 1924, in connection with rabbit destruction by the cyanide method.]

Location of Trial Area.

The locality in which the demonstration was given is on the terraces of the Awatere River in the Forestry Plantation Reserve a few miles from Seddon.

The major portion of this area is planted in twenty-year-old mixed pines, there being also a large stand of larch of the same age.

As the available open areas are to be planted in pines this season, freedom from rabbits is a primary consideration; therefore a trial by the cyanide method was solicited by the Forestry Department of Nelson. Rabbits completely destroy the commercial value of a plan-

ANOTHER RUN, SHOWING THE CONNECTION, AND ALSO DEMONSTRATING THE THOROUGHNESS OF THE DUST METHOD.

The exit in the middle foreground could quite easily be mistaken as belonging to the same system.

The only man who will have no time for the cyanide method will be the rabbit-trapper. Anybody who values rabbit skins more than the land which produces them will give the new method a wide berth; but for the farmer who knows the difference between the yields of a paddock free from rabbits and that of the same paddock when rabbit-infested, the new method should prove a boon and blessing greater than that offered by any of the known methods now in general use. A single trial suffices to carry the conviction that, in this method, the cleanest, cheapest,

tation by nibbling off the growing points of the young trees.

Condition of the Ground Worked Over.

(1) The lower river terrace, which averages nine feet above the river bed, consists mainly of sand, papa clay, and humus, with gravel at varying distances below the surface. The covering is close-growing grasses, with occasional clumps of tussock, gorse, and manuka. On the back between the first and second terraces is a thick growth of wild Irishman and New Zealand broom, interspersed with other native plants, a

few larch trees being present in certain portions. (2) The second river terrace, one half of which is open tussock country and the other half being covered with low-growing bushes of Muehlenbeckia. In both instances the ground is difficult to work, owing to the nearness to the surface of shingle. Humus is the predominant soil content, and papa is not in evidence excepting as a very deep subsoil. Rabbits were more plentiful among the Muehlenbeckia, and good warrens were secured for treatment. (3) The higher river terrace: Practically the whole of this is an old plantation, and as there were few warrens little attention was given to it.

The lower river terrace was selected as a suitable ground over which to work, as rabbits viewed from the bank could definitely be ascertained to have entered warrens. A number seen to be inhabited in this manner were treated accordingly.

Results.

In all, over two hundred warrens were treated, and although it was not possible to dig many of these out, none had been opened up in an interval of three days, so it is safe to assume that any rabbits in them perished.

Among them were instances in which twenty-five exits were found. In one case approximately eight ounces of powder was used, involving one hundred and fifty-six puffs of the machine. The total area in the reticulations must have been well over ninety yards. Those warrens in which rabbits were observed to enter were dug out at the end of twenty-four hours, and, excepting in one instance, when the direction was lost owing to great depth, all contained dead rabbits.

It was noticed particularly whether any attempt had been made to burrow through the turf in the exits, and one such case was found. This rabbit was in a very deep warren, and evidently escaping the direct discharge of the dust through the main tunnels, had come out afterwards, being enabled to reach the entrance and scratch ineffectually before succumbing in the poisonous atmosphere.

The pungent odour of the gas is noticeable even three days after treatment, and care had to be exercised in examination, the result of observations by an incautious worker being a severe headache.

Immediately after treating one short run of 12 yards a rabbit ran out, and getting no further than ten yards succumbed convulsively in two minutes. This was an exception, as all other warrens had been covered in before any movements of rabbits within could be detected.

It was found that in this country where the infestation was moderate, five to eight acres could be worked daily, and in winter conditions with the attendant short days prevalent, represented no more than a seven-hour day. For such a time nine and a-quarter pounds of powder were used.

Conclusion.

According to the results of this trial, the method may be expected to give satisfaction when a work of extermination is entered into in a similar class of country. In heavily bushed districts the method is less applicable, but it may be pointed out that other methods are similarly incompetent in a greater or lesser degree.

THE BLACK TAIL PRAIRIE DOG

In 1922 and 1923, Professor Otis Wade experimented with Cyanogas Calcium Cyanide for the control of the Black Tail Prairie Dog in Kansas. In this work a new method of applying Calcium Cyanide was tested. The treated burrows were left open and just as good results were obtained as if they had been closed. The gas given off from the Cyanogas Calcium Cyanide apparently formed a poisonous curtain of gas which killed the animal when it attempted to enter or leave the burrow. This method of treatment is known as the open-hole method of treatment. The reprint of Professor Wade's article is taken from the Journal of Economic Entomology, Vol. 17, No. 2, April 1924, page 339.

THE EFFECTIVENESS OF CALCIUM CYANIDE IN THE EXTERMINATION OF THE BLACK TAIL PRAIRIE DOG, *CYNOMYS LUDOVICIANUS* (ORD.)

By Otis Wade, *University of Missouri*

ABSTRACT

The efficiency of calcium cyanide as a control for prairie dogs was tested in 1922 and 1923 in Kansas. The flake form of the chemical was used in dosages of ¾, 1, 1½, and 2 ounces. The material was placed in each burrow entrance from 1 to 2 feet below the rim.

In three "dog towns" doses of 1, 1½, and 2 ounces were used and all entrances to dens closed. Total kills resulted in each instance. Eight infested areas were treated with ¾, 1, and 1½ ounce doses and all burrow entrances left open In the two tests with 1½ ounce doses total kills were obtained. Complete extermination resulted in one test with 1 ounce doses. In the remaining five tests where doses of ¾ to 1 ounce were used, the effectiveness varied from 90 to 99 per cent.

The killing power of the chemical in open burrows in an important factor, since the closing of burrows involves considerable time and labor

Preliminary tests by Professor F. L. Hisaw, Kansas State Agricultural College, indicate that calcium cyanide might be effectively used in the eradication of the pocket gopher, *Geomys bursarius* (Shaw). Doses of 1 and 2 ounces were used. The dose was placed in the main run through an opening made with a trowel After dosing the holes were closed. Effectiveness varied from 88 to 94 per cent

The use of calcium cyanide for the destruction of rodents was noted in a report by Professor George E Sanders of Nova Scotia in 1921 In

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his experiments the material was used with success in the control of a species of ground squirrel commonly referred to in that region as a "gopher."

Since calcium cyanide is receiving considerable publicity and is being strongly recommended by some as an efficient control for various noxious rodents, it seems desirable to report the results obtained with this material in tests made on the prairie dog in Kansas. These tests for the control of prairie dogs were made by the writer in May and August 1922 and April 1923.

The flake form of calcium cyanide was used throughout these experiments. The doses were placed down in the burrow entrances from one to two feet from the rim.

Except in three tests, all entrances to the burrows were left open after the calcium cyanide had been administered. This was done because it was thought if the material did not prove effective without closing all entrances, which is a slow laborious process, it would not be superior to methods already in use and it was the labor and attendant cost we wished to eliminate if possible.

The following data give the results of the first experiment:

Date	Area	Dosage	Entrances	Results
May 4, 1922	40 burrows	2 ounces	Closed	Total kill
May 5, 1922	58 "	1½ "	"	" "
May 5, 1922	157 "	1 "	"	" "
May 5, 1922	107 "	1½ "	Open	" "

Several inspections of the treated areas were made in May and June and a final inspection July 20. Not a living prairie dog could be discovered. A number of dead burrowing owls were noted in the entrances of open dens.

The second experiment was conducted August 3 with the following results.

Date	Area	Dosage	Entrances	Results
Aug. 3, 1922	88 Burrows	¾ to 1 ounce	Open	About 98% kill
Aug. 3, 1922	64 "	1½ ounce	"	Total kill

August 4 in the area treated with the smaller dose, three live dogs were seen and fresh work around the entrances of two dens was observed. The supply of calcium cyanide being exhausted these two live burrows were treated with heavy doses of carbon bisulfide to insure the death of the inmates. In the second town where more than one hundred prairie dogs were seen the previous day, there was no sign of life and the town appeared deserted. Eight dead burrowing owls were found

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in open entrances, three being taken from one burrow. They had evidently gone in the evening after the treatment, which was about 5:00 P. M. and were overcome by the gas, indicating that the effectiveness of the gas is maintained for several hours after the flakes are placed in the burrow entrances.

August 29 the two dog towns were again visited and no live prairie dogs were seen and no signs of fresh work observed about any of the dens. The dogs were completely exterminated.

A survey of the results obtained in 1922 showed satisfactory kills, where entrances to dens were left open, with dosages of 1 to 1½ ounces per burrow. In the two tests made, May 5 and August 3 with 1½ ounces of calcium cyanide to the burrow, total kills were obtained and the other tests made August 3 with ¾ to 1 ounce to the dose was very promising with a kill approaching totality. In view of these results it was decided to continue the work in 1923 with a series of tests using a straight dosage of 1 ounce per burrow, in order to learn if this apparently minimum dose would be entirely effective.

Date	Area	Dosage	Entrance
April 10, 1923	107 burrows	1 ounce	Open
April 10, 1923	250–300 burrows	1 ounce	Open

On April 14 one live dog and fresh signs around five or six dens were noted in the smaller town; in the second town no dogs were observed but there was some sign of their activities, and the owner of the farm said he had seen two dogs the day before. The kill in this experiment was considered to be about 99%.

Another experiment was made as follows:

Date	Area	Dosage	Entrance
April 12, 1923	48 burrows	1 ounce	Open
April 12, 1923	253 "	1 "	"
April 12, 1923	271 "	1 "	"

At the time these towns were treated many of the females were suckling young but as yet the young apparently were too small to leave their nests since none were seen above ground. On May 19 all three dog towns were checked. In the first town no dogs or signs could be seen which indicated a total kill; in the second town three or four old dogs were in evidence and a number of young; in the third town a number of old dogs were seen with a fair sized population of emaciated looking young crawling about in search of food. It was concluded that, at the time the burrows were treated, some of the young must have been about ready to leave their nests but did not, until forced by starva-

tion to do so, when the gas was no longer effective. The percentage of kill was estimated at 90% to 100% in these three towns.

Preliminary tests by Professor F. L. Hisaw, Kansas State Agricultural Experiment Station, indicate that calcium cyanide might be effectively used in the eradication of the pocket gopher. Doses of one and two ounces were used. The dose was placed in the main run through an opening made with a trowel. These holes were always closed after the dosage was administered. In these tests only isolated runs were used and only one dose was put in a run.

Calcium Cyanide dust was tried out in a few holes but proved not to have any advantage over the flakes. One hundred holes were given two ounce doses. In ninety-four of these successful kills were made, or about 94% effective. In 187 holes a one ounce dose was used. Of these, 21 holes were later found to be plugged indicating that the gopher was not killed. In the remaining 166 the treatment was successful, giving a killing percentage of about 88%. Professor Hisaw feels that the holes plugged were for the most part done before gas could be generated from the flakes. He found that his best results were obtained in the spring when the soil was moist, while his poorest results were in the fall when the ground was dry. From this he concludes that the gas generation depends on moisture in the soil. He was able to detect the gas in the run 15 feet from the opening but no quantitative tests were made.

These tests in the destruction of pocket gophers are preliminary and further work is necessary before safe conclusions can be made as to effectiveness under various conditions and the proper dosages to use.

Conclusions

Calcium cyanide when used at the rate of 1 ounce to each burrow was 90% effective or better. When used at the rate of 1½–2 ounces total kills were obtained.

The burrows need not be closed, thus making an appreciable saving in time and labor.

The moisture in the air liberates hydrocyanic acid gas which remains in the burrow for several hours diffusing in all directions. The prairie dogs are killed in their attempt to come through this curtain of toxic gas, very small amounts proving fatal.

Temperature apparently is not a limiting factor in the use of calcium cyanide providing the inmates of the burrows are active.

Preliminary experiments indicate that calcium cyanide may also be used for the destruction of pocket gophers.

The Black Tail Prairie Dog does not hibernate in Kansas. He may remain in his burrow during bad weather but on clear days he is active. This is the time when he most readily takes poison grain, hence it is of interest to know what success has been obtained by applications of Cyanogas Calcium Cyanide under winter conditions. On December 7, 1924, a snow and sleet storm occurred in Meade County, Kansas. December 8, was bright and sunny and although the ground was covered with ice and snow, the dogs were out of their burrows. A town consisting of 114 holes was treated, using one ounce per burrow. Twenty-four hours later only one live dog was found, representing a kill of over ninety-nine per cent. A town of similar size treated with poison grain at the same time showed fifteen dogs active at the end of a twenty-four hour period, representing a kill of only about eighty-seven per cent.

COLUMBIAN GROUND SQUIRRELS

Following the work of Professor Wade, the open-hole method was adopted for the control of the Columbian Ground Squirrel, *Citellus columbianus,* in the Northwestern United States. This rodent is responsible for an annual loss of approximately $10,000,000 to crops, principally wheat, in Washington, Idaho, Oregon and Montana. Extermination work is also being urged by authorities in Montana because of the possibility of its harboring the spotted fever tick in the Bitter Root Valley of Montana. In the experiments for the control of the Columbian Ground Squirrel, in the years of 1923 and 1924, over 2,500 burrows were treated with Cyanogas Calcium Cyanide and an average kill of 95% was obtained (Fig. 3-4). In February 1924, the Biological Survey, cooperating with the Extension Service, State College of Washington, issued instructions under title of "Use of Calcium Cyanide in Destroying Columbian Ground Squirrel", mimeograph sheet Bi-759. These instructions for treatment are as follows:

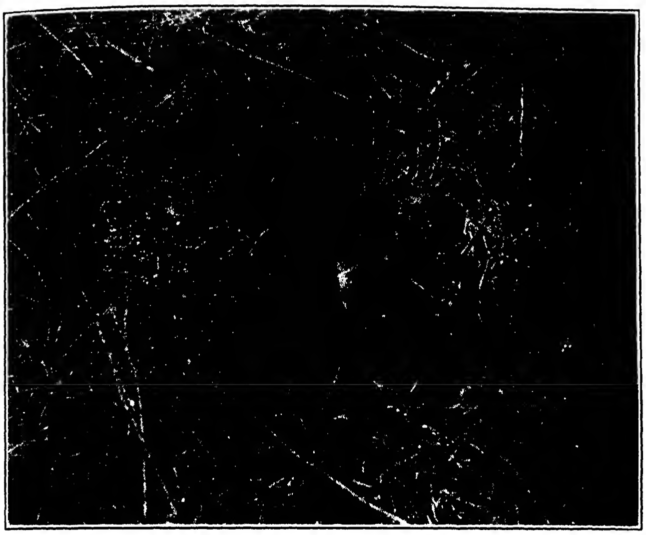

Fig. 3-4.—Dead Columbian Ground Squirrel at Entrance to Burrow Treated with Cyanogas Calcium Cyanide.

"To Use the Flakes: put the material into a small bucket fitted with a tight lid. This should be done in the open air, and the bucket should be kept closed except when in actual use. With a long-handled mixing spoon that will hold one ounce of the cyanide, throw one heaping spoonful deep into the open burrow. Cover the field thoroughly, as each burrow left untreated reduces the desired results. It is more practical to leave the burrow open, as this saves the time of one man and the effectiveness is only slightly, if any, increased where the burrow is closed.

To Apply the Dust: use a portable dusting machine provided with a six-foot hose and carried on the back. Insert the end of the hose well into the burrow, tamping loose dirt around it to prevent dust from escaping. Four strokes from the duster should force the equivalent of one ounce of material into each burrow.

The use of Calcium Cyanide is strongly recommended to supplement the poison grain, particularly in wild pasture lands surrounding cultivated fields. Where the work is carefully done a 95 percent clean-up, or better, should result from the first application."

This method of control became so popular that county drives were organized for the destruction of the squirrels (Fig. 4-4). Various towns cooperated with the farmers, certain days being designated by proclamation as "squirrel days". On these days business houses were closed and the townspeople went out to the farms to aid the farmers in applying the Cyanogas Calcium Cyanide.

Fig. 4-4.—Cyanogas Calcium Cyanide (drums in foreground) Ready for Distribution to Farmers for Control of Columbian Ground Squirrel. Office of Farm Bureau Agent Burford, Whitman County, Washington.

CALIFORNIA GROUND SQUIRREL

Immediately following the publication of Prof. G. E. Sanders' paper on the control of the Richardson Ground Squirrel in Canada, experiments were started in California with Cyanogas Calcium Cyanide on the control of the California Ground Squirrel, *Citellus beecheyi.* We have conducted experiments for several years, the results of which are tabulated in Table I-4.

Fig. 5-4.—Control of California Ground Squirrel. Calcium Cyanide Measured in Large Spoon Then Placed Well Down in Burrow.

One of the chief difficulties encountered in the work was the checking of the results. If a given area is treated, and the holes closed, in a comparatively short time, squirrels from the surrounding area move into the treated area and scratch open the closed burrows. Even though a 100% kill was obtained, a later check would show open holes and indicate an apparent lower efficiency than actually existed.

In the early work the closed-hole method was used entirely but in later experiments the efficacy of the open-hole method was demonstrated (Fig. 5-4). In using the open-hole method the determination of the kill was made by closing the hole the day after treatment. A count was later made of the holes which had been opened. In all the experiments cited, an open hole at the time of checking was considered to represent a squirrel which had not been killed. The summary given in Table I-4 shows that Cyanogas Calcium Cyanide is as effective, if not more so, than any other method employed in squirrel control.

TABLE 1-4
California Ground Squirrel Control Experiments, California
1921-24

No.	Location	Date	Weather	Soil	No. Holes Treated	Mat. Used	Amt. Per Burrow	Date Checked	Holes Closed	Holes Open	Percent Efficiency	Remarks
1	Stockton	11- 3-21	Clear 90°F.	Heavy Adobe	100	Flake	2.24 oz.	12-21-21 1- 8-22	84 69	16 31	84. 69.	
2	Fresno Co.	12- 5-21	Clear 95°F.	Dry Sandy	236	Flake	1.52 oz.	12- 8-21 12-28-21	235 228	1 8	99. 97.	2-18-22 This plot rechecked 13 holes open, 8 live squirrels noted.
3	Fresno Co.	12-27-21	Clear 70°F.	Heavy Red	71	Flake	2. oz.	1- 6-22 1-20-22	68 70	3 1	96. 98.	All holes open 1-6-22. Retreated with 4 oz. dose.
4	Fresno Co.	1-18-22	Cloudy 45°F.	White Ash	534	Flake	2. oz.	1-25-22 2-17-22	399 324	135 210	75. 61.	19 live squirrels seen on plot. 4 busily engaged opening closed holes.
5	Fresno Co.	2-15-22		Moist Red	2191	Flake	1.76 oz.	2-17-22 2-24-22	2159 2088	32 103	98. 95.	
6	Fresno Co.	2-16-22		Moist Sandy	162	Dust	1.33 oz.	2-23-22	157	5	97.	
7	Fresno Co.	5-14-22			2779	Flake	2.15 oz.	5-24-22	2593	186	93.3	
8	Santa Monica Canyon	5-22-22			949	Flake	2.2 oz.	5-30-22	908	41	96.0	About 150 acres.
9	Walnut	11- -22			6323	Dust	2.53 oz.	12- 1-22 12-26-22	5870 114	453 21	92. 84.	Treated four holes missed first application.
10	Santa Monica	11-27-22			135	Dust	2.09 oz.	1- 1-23	127	8	94.	
11	La Verne	12- 9-22			233	Dust	2. oz.	12-16-22	202	31	86.	Most holes open along fence bordering plot indicating reinfestation.
12	Walnut	12-18-22			122	Flake	2. oz.	12-22-22	114	8	93.	Hillside heavy infestation.
13	Ventura Co.	12-24-22			75	Flake	2.24 oz.	12-28-22	69	6	93.	
14	Porterville	12-28-22		Adobe	142	Flake	2. oz.	1- 5-23	98	44	69.	
15	Puente	1- 4-23		Dry Recent Plowed	176	Flake	2.27 oz.	1-10-23	156	20	88.6	
16	Arcadia	1- 5-23			38	Flake	2.1 oz.	1-10-23	38	0	100.	
17	San Marino	1- 5-23			40	Flake	2. oz.	1-10-23	39	1	97.1	Heavy infestation in banks of wash.
18	Huntington Dr.	1-5-23			41	Flake	1.97 oz.	1-10-23	39	2	95.1	
19	Orange Co.	1-11-23			120	Flake	2. oz.	1-16-23	112	8	93.3	About half holes open result of reinfestation.
20	Orange Co.	1-11-23			200	Dust	2. oz.	1-16-23	180	20	90.	
21	Fresno Co.	2-13-23		Moist Sandy	290	Dust	1.54 oz.	2-23-23	283	7	98.	
22	Fresno Co.	2-18-23		Moist Red	104	Dust	1.34 oz.	2- 5-23	91	13	87.	
23	Santa Monica	2-28-23	Fair	Hard Rocky	502	Flake	2.07 oz.	3- 9-23	499	3	99.	
24	Santa Monica	3- 8-23	Fair	Hard Rocky	2878	Dust	.73 oz.	3-16-23	2654	224	92.	
25	Merced Co.	3-31-24	Fair Warm	Light Sandy Loam	220	Flake	2. oz.	4- 2-24	215	5	97.7	Well established colonies, good sized.
26	Merced Co.	3-31-24	Fair Warm	Light Sandy Loam	62	Flake	2. oz.	4- 2-24	62	0	100.	
27	Merced Co.	3-31-24	Fair Warm	Heavy Clay	110	Flake	2. oz.	4- 2-24	110	0	100.	Very large colonies.
28	Obispo Co.	4-16-24	Fair Warm	Firm Adobe	110	Flake	2. oz.	4-24-24	99	11	90.1	High knoll, not much chance for reinfestation.

Note:—Experiments 1921-23 Closed Hole Method.
Experiments 1924 Open Hole Method.

Summary:—Closed Hole Method 18,441 holes, 92.2% control.
Open Hole Method 502 holes, 96.8% control.

WOODCHUCKS

Experiments with Cyanogas Calcium Cyanide for the control of the Woodchuck or Groundhog were carried on by Professor W. P. Flint, State Entomologist of Illinois, in 1923. He found that the best method was to place one tablespoonful (about 1 ounce) of Calcium Cyanide Flakes as far into the burrow as possible with a long handled spoon (Fig. 8-4). The entrance to the burrow was closed immediately with sod and damp earth. Similar results were obtained by Prof. J. J. Davis in the neighboring state of Indiana.

Fig. 6-4.—The Wary Woodchuck.

The Groundhog is a serious pest in the middle-western United States due to its habit of burrowing in the levees along the streams. At the time of the spring freshets, the water rushes down these burrows, often causes a break at these points, and a flooding of miles of the surrounding territory results (Fig. 7-4).

Fig. 7-4.—A 100 ft. Break in Levee Caused by High Water Working Through Woodchuck Holes in Indiana.

Due to the great interest in the control of the Groundhog in this area, Mr. Carlyle Carr of the Biological Survey co-operated with Professor Flint and Professor Davis in this territory in the spring of 1924. In May, 1924, the Biological Survey, United States Department of Agriculture, issued a mimeograph instruction sheet, Bi-768:

Fig. 8-4.—Treating Woodchuck Holes in Open Field with Calcium Cyanide. Note Opening to Burrow in Foreground.

"Directions for Destroying Wood Chucks or 'Groundhogs'

1. Make a complete survey of your farm for woodchuck burrows.

2. Treat each used hole with 3 tablespoonfuls (1½ ounces) of carbon bisulphide, or 1 tablespoonful (about 1 ounce) of calcium cyanide flakes as follows:

(a) Pour the carbon bisulphide on a small wad of cotton, rags, waste, or other absorbent material and throw or place well down into the burrow.

(b) Place the calcium cyanide flakes as far into the burrow as possible with a long handled spoon.

3. Close tightly the entrance to burrows immediately with sod and damp earth, taking great care to avoid loose sand or dirt falling upon the fumigant.

4. Examine all treated burrows after the lapse of one week and retreat the reopened burrows.

IMPORTANT

Game and fur-bearing animals are protected by law. Be careful to avoid treating burrows or dens occupied by these animals. Treat woodchuck burrows during the active season only."

County wide campaigns were held in several counties in the Mid-west in 1924, with such success that additional counties followed their lead in 1925 (Fig. 9-4). In 1925, a state-wide campaign for extermination of woodchucks was successfully conducted in New York State by Professor C. R. Crosby, co-operating with the United States Biological Survey. In New York State the woodchuck is injurious due to its feeding habits and to the liability of farm animals breaking their legs in the burrows scattered about the fields.

Fig. 9-4.—A Few Less Groundhogs in Iowa.

RATS

The development of the use of Cyanogas Calcium Cyanide "A" Dust for the destruction of rats around outbuildings and in city dumps is principally due to the work of Mr. Leo K. Couch of the Biological Survey, United States Department of Agriculture. An account of his experiments, as approved for our publication by the Biological Survey, is given below.

"CALCIUM CYANIDE EXPERIMENTS ON RATS"

By Leo K. Couch,
Biological Survey.

"In November, 1923, the possibilities of using calcium cyanide in rat control were first tried out on the city dump of Yakima, Washington. The practical application of this material having been worked out on Columbian ground squirrels, attention was turned to other rodent pests where recommended methods were not entirely satisfactory. Cooperating with representatives of the American Cyanamid Company, calcium cyanide dust was forced into rat burrows in the fills with a duster. Approximately ten pounds of dust were used on a small portion of the dump, with about two ounces to each burrow, measured by eight full strokes of the duster. This dose varied with the extent of each burrow system and the surrounding exits where the dust escaped. Rats would run from the burrows in a stupefied state. Many were killed with clubs, and many never reached the burrow entrance. In this experiment, about fifty rats were killed on the surface.

"In December, 1923, the experiments were continued at the sanitary fills of Olympia, Washington. Dust was forced into burrows in the same manner as at Yakima. The first application of four pounds of dust killed fifty rats on the surface. A week later the same quantity was used, resulting in a pile of thirty dead rats. Reinfestation from nearby docks and wharves had refilled the burrows. Four subsequent dustings, at intervals of ten days, accounted for one hundred and fifty rats with the use of about thirty pounds of calcium cyanide. We were satisfied that the number of rats brought to the surface was not a true indication of the number killed. In an older part of the dump, where only three came to the top, complete excavation of the burrow

disclosed forty-three dead rats packed together in a hollow recess. From their position it appeared that the first rats had been overcome while trying to escape, thus blocking the exit of those behind.

"Experiments were carried out at the city dumps of Anacortes and Chehalis, in March and April, 1924. Only a few rats were killed in each case, owing to the large quantity of bulky waste, such as automobile fenders, etc. The gas could not be controlled as readily as where the ground was solidly packed. Rats would be driven from the "gassed" area, only to return, apparently not greatly disturbed. It was thought that two men operating dusters could lay down a "dust barrage", working toward each other. This was tried out in a limited way on the more open section of the Olympia fill. It proved more successful than using one machine, but was attended by considerable waste of cyanide.

"In July, 1924, rats were reported killing game birds at the State Game Farm, near Steilacoom. Investigation showed that the rats were using mole burrows in the open field. Calcium cyanide was pumped into these burrows, and we accounted for thirty-six dead rats on top. Approximately fifteen pounds of dust were used—more material being required on account of the extensive burrow system.

"In October, 1924, after the Yakima fills had been moved to a new location, twenty-five pounds of calcium cyanide were pumped into them—resulting in a kill of one hundred and fifty-four rats on the surface. The following November a demonstration was again held, with the city officials as witnesses. It was estimated that at least one thousand were killed in the burrows. This good showing was made with about twenty-five pounds of calcium cyanide, at a time when most of the rodents had deserted the old dumps for the new fills.

"A rat survey among poultrymen in 1920 showed the seriousness of this rodent to the poultry industry. Although conditions on poultry farms are all different, yet it was thought calcium cyanide could be aplied in most cases where trapping and poisoning failed. On January 29, 1925, the farm of August Wax, King County, was visited. He had 3,500 hens housed in four buildings—two of them being one hundred and twenty feet long and the others two hundred feet. They all had concrete foundations and floors, six inches through the concrete and dust boxes. Although it stormed all day, about twenty-five pounds of calcium cyanide

were pumped into the buildings. One hundred and sixty-three rats were picked up dead or killed with clubs. Mr. Wax reported later that he had seen only two or three rats since the demonstration, although he had been looking around every night with a flashlight. He believed we had exterminated two or three thousand of the animals, as formerly he had seen hundreds on his tours of inspection.

"With the results of the foregoing experiments as a background, it is safe to say that calcium cyanide will be of value as a rat-control method. Its use is limited, however, to situations where the gas can be controlled and not injurious to human life, poultry, and livestock. When the operator fills the machine and pumps out the material in the open air, there is little danger.

"The killing power of calcium cyanide appears to be the greatest on still quiet days when there is considerable humidity, and on days following showers. When wind is encountered the material is wasted through rapid diffusion. Perfect weather conditions prevailed on the day we gave a demonstration on the F. H. Crowder farm, near Tenino, Washington. Cyanide was forced under buildings and into outside burrows. Fourteen rats were killed on the surface. The previous week he had lost forty baby chicks and nine old hens, but the losses ceased after our demonstration.

CAUTION

"Calcium cyanide is a deadly poison. It should be kept closed air-tight in the original container and only transferred to the duster in the open air. Read the precautions printed on the container label. Keep the container out of reach of children, irresponsible persons, and livestock."

A description of Mr. Couch's experiments of particular interest to poultrymen is taken from The Washcoegg, Volume III, No. 3, p. 7, July, 1925.

"KILLING RATS WITH CALCIUM CYANIDE"

By Leo K. Couch, Biological Survey, United States Department of Agriculture.

"As a supplement to the trapping, poisoning and rat-proofing methods recommended for controlling rats, the U. S. Biological Survey has developed a new method which should prove of value around rat-infested poultry plants in Western Washington.

"Calcium Cyanide in powder form is forced into rat burrows under building floors and foundations. This is done with a portable dusting machine. The dust is forced through a hose, entering the rat harbors in the form of a smoke-like spray. The dust, coming in contact with moisture in the air, liberates hydrocyanic acid gas in a concentration in which no animal can live long. The use of this material is limited, however, to situations where the gas can be controlled.

"A number of successful applications have been made on West Side poultry farms. In co-operation with Mr. W. W. Henry, King County Agent, a control demonstration was held at the farm of August Wax, six miles east of Kent. On this farm were four buildings, two of them 200 feet long and the others 120 feet in length, all having concrete foundations and floors six inches thick and housing 3,600 hens. Mr. Wax had used every precaution known to rat-proof these buildings, but the animals burrowed under the cement foundations, worked holes in the cement floors and burrowed through the dust boxes. Mr. Wax stated he trapped and poisoned with little success, as the rats had access to the grain, mash, eggs, and young and sick poultry, with the result that they were causing him a loss of $1,000 per year. Although it stormed all day, the cyanide dust was pumped under the buildings and 163 rats killed either conveniently picked up or pulled out of the burrows dead. These were only a part of the rodents actually killed. Mr. Wax advised he visited his houses night after night for some time, looking over and under the floors carefully with a flashlight. Only two live rats were seen, where formerly he had observed a hundred.

"There are two types of dusters capable of forcing Calcium Cyanide effectively into rat burrows. The bellows type is the largest. This is carried on the back and has a capacity of fifteen pounds. The dust is forced out by means of a bellows handle operated with the right hand, through a hose and nozzle held by the left hand. This machine is adapted for large poultry plants, city dumps and garbage heaps. On badly infested farms, where this method can be used, it should be applied at least once a week, and thereafter as the rats appear. On account of the migratory habits of the rats, it would pay to have a duster and materials always on hand.

"A small duster made similar to a bicycle pump has recently been devised for rat work and this more nearly

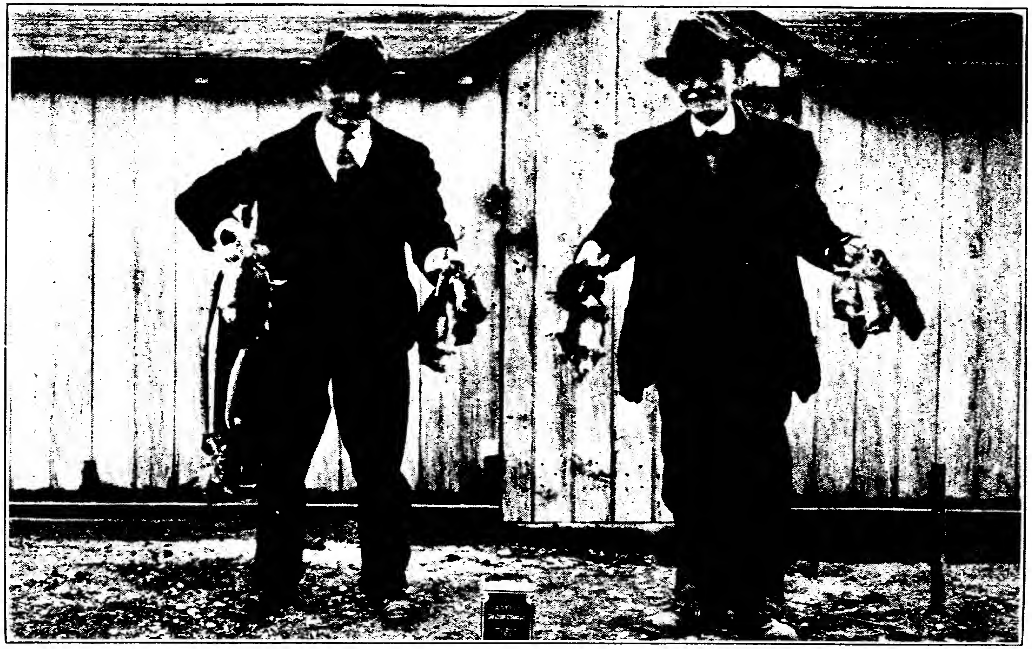

Fig. 10-4.—Effective Demonstration of Rat Control with Cyanogas Calcium Cyanide, Vineland, New Jersey.

Fig. 11-4.—Less Rats—More Eggs, Vineland, New Jersey.

meets the requirements of the average poultryman. The machine rests on the ground, the dust being pumped into the burrows through a flexible hose.

"The U. S. Biological Survey, co-operating with the Extension Service of Washington State College, through the various County Agents, is planning a rat campaign the coming fall and winter on Western Washington farms and where feasible to use the Calcium Cyanide method, it will be recommended. However, it must be kept in mind that when the rats are exterminated, rat-proofing must be planned to prevent a recurrence.

"Plans are being formulated for the Washington Cooperative Egg and Poultry Association to keep dusters and Calcium Cyanide in stock. The cost of the dust and material are low in comparison with its effectiveness. Where not practical to use Calcium Cyanide, poisoning and trapping should be followed. The rat has kept pace with the growth of the poultry industry and is now responsible for an annual loss of thousands of dollars. Operating expenses must be met before the poultryman sets aside a profit. What the rat eats and destroys should be in the savings account of the grower."

Based on the above mentioned experiments, the Biological Survey cooperating with the State College of Washington has issued the following sheet of instructions, Bi.-825, August, 1925:

"KILLING RATS WITH CALCIUM CYANIDE"

"When rats have access to unlimited quantities of food, as found in garbage heaps and on the average farm, controlling them by poisoning or trapping often fails. In such situations the Biological Survey has developed a new method which should be successful. Where rats burrow under poultry houses and other farm buildings having fairly tight floors, calcium cyanide dust pumped into the burrows with a portable dusting machine has been found very effective. The cyanide is forced through a hose, entering the rat harbors in the form of a smoke-like spray. When the dust comes in contact with moisture in the air, it liberates hydrocyanic-acid gas, in a concentration of which no animal can live long. It must be remembered that the fumigation method will not be successful under all conditions, but only where the concentration and spread of the gas can be controlled.

Fig. 12-4.—Rats Killed in City Dump with Calcium Cyanide, Portland, Ore.

"There are two approved types of dusters capable of forcing cyanide into rat burrows. The bellows type, carried on the back, is the largest, being adapted for use around large poultry plants, city dumps, and sanitary fills. The machine should be operated at least once each week in badly infested places, and thereafter as often as necessary to keep the rats under control.

"A smaller duster, similar to a bicycle pump, has recently been devised for rat control work, and this more nearly meets the requirements of the average poultryman. The machine rests on the ground, and the dust is forced out through a flexible hose. This type permits more economical use of material than the large duster.

"On account of the migratory habits of rats, it will pay the poultryman to keep a duster and a supply of the chemical on hand. The cost of calcium cyanide is low compared with its effectiveness. Its use should not be relied upon alone, but only as a supplement to the methods recommended for poisoning and trapping. Cleaning up the premises and rat-proofing the buildings will go a long way toward keeping rats from becoming troublesome."

Fig. 13-4.—Rat Control in England. Making Application of Cyanogas "A" Dust to Entrance of Rat Burrow.

Fig. 14-4.—Results of the Treatment with Cyanogas.

VIZCACHA

The Vizcacha, *Lagostomus maximus,* is a burrowing, nocturnal rodent, slightly larger than a cat, which is native to the Argentine. They are social animals inhabiting dens with from one to many openings. One interesting characteristic is their habit of gathering pieces of wood or chips which they place near the entrance to their burrows (Fig. 15-4).

A series of experiments in the control of this rodent with Cyanogas Calcium Cyanide were conducted by Mr. F. E. Todd in the Argentine in 1924 and 1925. It was found that the Vizcacha was very hard to kill, requiring a heavy dose of Cyanogas Calcium Cyanide "A" Dust. A dose of 150 grammes was required for each burrow, except in the case of large dens having from 4 to 8 openings when a maximum dose of 500 grammes to the entire den proved effective.

The method of treatment consists of blowing the dust into one or several openings of the den until it emerges from all of the others after which the entrances are closed. If a convenient duster is not available, the dust may be placed well down in each opening with a longhandled spoon and the opening closed with a tuft of sod.

Fig. 15-4.—The Vizcacha, Entrances to Nest—Note Collection of Sticks Made by the Animal Near Entrance.

THE GOLDEN MOLE AND THE CAPE MOLE-RAT

Cyanogas Calcium Cyanide has been used with success for control of the Golden Mole, *Chrysochloris sp.* and the Cape Mole-rat, *Bathyergus maritimus*, infesting golf courses in South Africa. The original work was supervised by the Division of Entomology, Union of South Africa. A brief account of the method of application and the successful results obtained is taken from Journal of the Department of Agriculture, Union of South Africa, Vol. VIII, No. 6, June 1924, page 546. The second report is from the same Journal, Vol. IX, No. 3, Sept. 1924, page 191.

Moles and Mole-rats.—According to information supplied to the Division of Entomology, the Port Elizabeth golf course has been seriously infested with golden moles and mole-rats for the past fifteen years, and, during that period, something in the neighbourhood of £800 has been expended in attempting to control the nuisance by trapping the creatures. Although thousands were caught in traps, their destructive work continued to such an extent that the Eastern Province Entomologist was asked by the executive committee of the club to devise more effective means of control. Acting on the advice of this Division, liquefied hydrocyanic acid gas and calcium cyanide were tried last November. Through the courtesy of the Cyanide Gas Company, Claremont, a supply of the liquid was obtained free of charge, and Mr. C. D. Grier, South African representative of the American Cyanamid Company, kindly presented calcium cyanide for the experimental work.

The liquid cyanide was used in the following manner: The mound of soil ejected by the rodents was first removed with a spade and the opening of the burrow exposed. An ampoule, or glass tube, containing twelve cubic centimetres of liquid was partly inserted into the burrow and then broken by means of a short iron rod. After doing this the mouth of the burrow was tightly plugged with a handful of grass or woodwool, and a quantity of soil was placed over this and firmly rammed with the spade. Calcium cyanide is manufactured in the form of thin, greyish flakes, and the method of application was to insert two tablespoonfuls, approximately two ounces by weight, into each burrow. The moisture present reacts on the calcium cyanide and liberates hydrocyanic acid gas. Before a burrow was charged with either of these chemicals it was first carefully examined to see that there was no obstruction.

From the middle of last November until 25th March, 1924, about four hundred holes were treated with liquid cyanide and fifty-six with calcium cyanide. The method adopted, when judging the results of the work, was to examine each fresh mound of soil that was ejected by the rodents from their burrows to ascertain if the hole had been previously treated. Since the commencement of the work only two have had to be retreated; the retreated burrows, however, were close to rough ground in which the rodents were numerous. Before these experiments were made, the rodents were very numerous in the greens, but during the past two months they seem to have been eliminated. Surrounding the greens there is a large area of rough ground which is infested with the rodents, the treatment of holes in this ground being undertaken in April.

Calcium Cyanide for Moles.—For some time past the Eastern Province Entomologist, Mr. D. Gunn, has been supervising the control of the golden mole and mole rats inhabiting the rough ground beyond the fairways of the Port Elizabeth golf links. During June last, Mr. Gunn treated over forty burrows with calcium cyanide, and since then none of the treated burrows nor those in their immediate vicinity have been reopened. Other burrows were treated with liquid cyanide, but these in many cases have had to be retreated. It would, therefore, appear that the calcium cyanide is much more effective. Earlier treatments with calcium cyanide conducted in November, 1923, were equally successful as for over nine months none of these had been reopened. The cost of treating a burrow with calcium cyanide worked out, with railage and other charges, at two pence per burrow whilst the less satisfactory liquid cyanide cost sixpence. The effectiveness of the calcium cyanide is thought to be due to the slow evolution of the gas.

THE TALTUZA

The Taltuza, *Heterogeomys torridus*, is a large pocket gopher injurious in the coffee plantations of Guatemala. A report on the use of Cyanogas Calcium Cyanide for the control of this rodent has been published by the Director of Agriculture in connection with his report on the use of this material for the control of the Zompopo—The Leaf-cutting Ant. We are reproducing this report from Boletin de Agricultura Industria Y Comercio de Guatemala, Vol. III, No. 2, Feb., 1924, p. 54-55, together with an English translation.

Lucha contra el zompopo (Atta Sexdens)

La American Cyanamid Co. de Nueva York, remitió a la Dirección General de Agricultura hace algo mas de cuatro meses una buena cantidad como muestra de un producto insecticida, el **Cianuro de Calcio** a cuya fabricación se dedica.

Con la muestra recibida hemos estado haciendo numerosos ensayos para conocer el valor del referido ingrediente para la destrucción del Zompopo. Los resultados obtenidos, suficientemente satisfactorios, permiten recomendar el producto como digno de que se generalice su uso.

El Cianuro de Calcio tal como los fabricantes lo ponen a la venta es una sustancia grisácea, parecida al cemento, que emite continuamente a las temperaturas ordinarias un olor penetrante, desagradable. Ese olor es debido al ácido cianídrico que continuamente se desprende del producto y al cual se deben sus efectos insecticidas.

El producto nos llegó en dos estados de pulverización, una fórma granulada que emite vapores en menor cantidad pero durante más tiempo, y otra finamente pulverizada que se vaporiza con mayor violencia pero por la misma razón es de efectos menos duraderos.

El Cianuro de Calcio se usa introduciendo una cantidad apropiada y variable según la importancia del zompopero, en las entradas de éste y haciéndolo penetrar a la mayor profundidad posible, después de lo cual se tapa la entrada con tierra bien comprimida. Por la conveniencia de que el insecticida penetre bien adentro de las galerías, nosotros hemos encontrado preferible el producto reducido a polvo fino y el cual se inyecta con facilidad usando un fuelle cualquiera como los que se usan en las cocinas para avivar el fuego, o aun los que sirven para fumigar las abejas. En los ensayos efectuados se usó un fuelle especial proporcionado por la misma casa y con el cual el tratamiento de los zompoperos es mucho más eficaz aunque absorbe, por lo mismo una cantidad mayor de material. Por excavaciones ulteriores, se ha constatado que el material penetra en todas las galerías, hasta profundidad de más de un metro. Todas esas galerías se encontraron repletas de insectos muertos, pero en honor a la verdad debe advertirse que en otras galerías situadas algunas pulgadas más abajo de las anteriores, el primer tratamiento no había sido suficiente para destruir los insectos. En los zompoperos muy grandes el procedimiento por seguir sería, en consecuencia, hacer una primera fumigación por las galerías que se notan desde la superficie y excavar hasta una media vara por ejemplo, para descubrir nuevas bocas por las cuales se hace posible inyectar el insecticida hasta mayores profundidades. Pero entre este nue-

vo tratamiento y el primero deben dejarse pasar algunos días por que los insectos no sucumben instantáneamente, bajo la acción de los gases asfixiantes y al excavar demasiado pronto los lugares tratados, se daría salida a éstos, impidiendo su buen efecto.

Recordamos que por los meses de Marzo y Abril, acaban de desarrollarse las hembras de los zompopos que con las primeras lluvias salen a poner huevos y formar nuevas colonias.

Es en consecuencia de la mayor importancia intensificar la lucha contra tales insectos por los meses indicados y el de Mayo, ya que con cada hembra que se destruya antes de que haya efectuado su postura, es un zompopero entero que se evita.

El Cianuro de Calcio ya citado, el Sulfuro de Carbono, el Carburo de Calcio, o la excavación de los nidos, cualquier procedimiento y el que se tenga más a la mano, debe emplearse con energía y por el mayor número de interesados para acabar con tal plaga y empleándose en la época en que entramos, el trabajo necesario para llegar a un resultado eficaz será mucho menor.

El Cianuro de Calcio granulado recibido, se distribuyó en parte, entre algunos propietarios que sufrían daños en sus plantaciones, de parte de las taltuzas. Varios nos han informado de un resultado también satisfactorio. Más o menos deben ponerse dos onzas del producto lo más adentro que se pueda en la galería cuya boca se tapa en seguida con un puñado de paja o con tierra, y cuando las galerías se notan a lo largo de la superficie del terreno, conviene abrir chimeneas a cada cinco piés de distancia por las cuales se itroduce una onza de Cianuro de Calcio tapando en seguida con un puñado de zacate pero con la precaución necesaria para no derrumbar la galería e impedir así la fácil expansión del gas asfixiante. Las galerías no tardan en saturarse de gas y se mantienen asi por un tiempo suficientemente largo para asfixiar los roedores que se encuentran en ellas.

Procediendo con cuidado en el manejo del Cianuro de Calcio, los peligros que resultan no son extraordinarios pero es necesario saber que el gas que emite debe respirarse lo menos que se pueda y que después de haber tocado el material no deben llevarse las manos a la boca. Es también necesario evitar que el polvo entre en contacto con la carne viva por las lastimaduras o heridas que se pudieren tener en las manos.

BULLETIN OF AGRICULTURE, INDUSTRY & COMMERCE

FIGHT AGAINST THE "ZOMPOPO" (*Atta Sexdens*)

"The American Cyanamid Co., of New York, sent to the Director General of Agriculture about four months ago a good sized sample of an insecticide, Calcium Cyanide, which the said company manufactures.

We have been using the sample in a large number of trials in order to determine the value of the said product in the destruction of the Zompopo. The results obtained are sufficiently satisfactory to warrant recommending the said product as suitable for general use.

The Calcium Cyanide, as it is sold by the manufacturers, is a gray substance, similar to cement, which sends forth steadily, at ordinary temperatures, a penetrating odor which is very offensive. This odor is due to the hydrocyanic acid gas which is continually given out from the product and to which it owes its insecticidal properties.

The product was received by us in two grades of fineness, one in a granulated form which gives out vapors in small quantity but of longer duration, and the other finely ground which vaporizes more quickly and for this reason is more rapid in its action.

The Calcium Cyanide is used by blowing through the entrances of the nests an amount which varies according to the size of the nest and forcing it as deep as possible, and then the entrance is covered with earth well compressed. In order that the insecticide shall penetrate well inside the galleries we have found that it is preferable to use the finely ground powder, which is forced in with any kind of bellows such as those used in kitchens to make fire or even those used to fumigate bees. In the trials made, a special bellows furnished by the manufacturers was used and with this the treatment of the ant nests is more efficient, although a larger amount of the material is used for the same purpose. Diggings made later on showed that the material penetrated throughout all the galleries up to a depth of more than one meter. All the galleries were found full of dead ants although for the sake of truth it must be stated that in some other galleries, a few inches below the upper ones, the first treatment was not sufficient to destroy all the insects. In the very large nests the process to be adopted would consequently be to make the first fumigation through the galleries seen

on the surface, and then to dig to a depth of half a yard, for example, in order to discover new entrances through which to apply the insecticide to greater depths. But between the first and the second treatment a few days should elapse because the insects do not die at once under the effects of the deadly gases and if the digging is done too soon the gases would escape and their effect would be impaired.

We call attention to the fact that by the months of March and April the females of the Zompopos attain their full development and that at the first rainfalls they come out to lay their eggs and create new colonies.

Consequently, it is of the greatest importance to intensify the fight against these insects during the said months and also in May, since each female destroyed before having a chance to lay its eggs means prevention of a new nest.

The said Calcium Cyanide, as well as Carbon di-sulphide, Calcium Carbide, or the digging out the nests, or any process available, must be applied efficiently and by the largest number of interested persons in order to exterminate the pest, and doing the necessary work in the season we are entering now to attain satisfactory results.

The Calcium Cyanide received in granulated form was partly distributed among some farmers whose plantations were attacked by the "Taltuzas". Several of said farmers have informed us that they have obtained satisfactory results. About two ounces of the product should be introduced as far inside the gallery as possible and the entrance covered at once with straw or earth, and when galleries are seen along the surface of the ground it is well to open chimneys five feet apart through which one ounce of the Calcium Cyanide is dropped and the opening closed at once with grass but being careful not to break the gallery down as it would prevent the spreading of the lethal gases. The galleries are very soon saturated with gas and kept that way for a time long enough to kill all the rodents inside.

If the Calcium Cyanide is handled with care the danger associated with its use is not great, but it is necessary to know that the gas produced by it is to be breathed as little as possible, and after having handled the material you must not put your hand to your mouth. It is also necessary to keep the powder from entering into contact with any wound or open flesh in the hands."

CRAYFISH AND LANDCRABS

The "Prairie Crayfish", *Cambarus hagenianus*, occurs in some sections of Mississippi as a serious field pest. This Crayfish occurs on comparatively high land, making a burrow deep enough to reach the water level. In the infested area from 5,000 to 10,000 burrows per acre are common. During rains, the crayfish come out and feed on corn, cotton, and similar crops. Professor R. N. Lobdell, of the Mississippi A. & M. College has used Cyanogas Granular Calcium Cyanide for the control of this pest. The treatment should be made sometime between the middle of February and cotton-chopping time. Each burrow should be treated with one-half teaspoonful of material, and the burrow closed.

Fig. 16-4.—Land Crab Killed with Cyanogas Calcium Cyanide. Dead Crab at Entrance to Burrow. Coconut Grove, Fla.

A species of *Cambarus*, possibly the above species, occurs in Illinois where control experiments have been conducted by Professor C. C. Compton. Out of 177 holes treated with one-half ounce dose, two were reopened and three made new holes. A second application resulted in a complete kill. Later four acres were treated with equally good results.

Fig. 17-4.—Florida Gopher (Turtle) Killed with Cyanogas Treatment. Note Characteristic Shape of Burrow. Coconut Grove, Fla.

Throughout the tropical world in the low coastal regions, Land Crabs are a serious pest. On the east coast of Florida, Land Crabs, *Cardisoma guanhum*, are very destructive to winter-grown tomatoes. In this area, in 1924, our Mr. R. G. Eidson conducted a series of experiments using from one-third to two-thirds of an ounce Cyanogas Calcium Cyanide "A" Dust to each burrow. The material was applied with a spoon. A kill of 96 to 100 per cent was obtained (Fig. 16-4). In 1924, similar results were also obtained in

the experiments for the destruction of Land Crabs in Panama Canal Zone. Following the experimental work, Cyanogas Calcium Cyanide was used by the Military authorities for this purpose. They consider that Calcium Cyanide "has proven to be the best eradicator of this pest over all other methods or chemicals heretofore discovered. When Cyanogas is used, it not only destroys the pest while in his hole or habitat, but that hole will never again be used by other crabs, therefore, causing new holes to be made, in which event they are more easily discovered and disposed of".

LAND TURTLES

The Land Turtle, *Gopherus polyphemus*, is oftentimes a troublesome pest. Experiments have indicated that a two or three ounce dose of Cyanogas Calcium Cyanide "A" Dust may be used in their control. Material should be placed well down in the burrow and the entrance closed with the heel (Fig. 17-4).

Ants

In general ants are not considered to be of great economic importance. This is probably true if one considers only the common lawn and garden varieties of the temperate regions. However, on consideration of the ants in the tropics and particularly tropical America, we find that they are of great economic importance.

LEAF-CUTTING ANTS

The enormous losses caused by this insect are well shown by Dr. C. H. T. Townsend, entomologist for the State of Sao Paulo, Brazil, in an article entitled "A Billion Dollar Insect—Its Elimination: The Sauva Ant." The following paragraphs are quoted from the Almanak Agricola Brasileiro, 1923, p. 251.

"The sauva or leaf-cutting ant of tropical America, is, from the standpoint of agriculture, the most destructive insect in the world. It undermines and overruns the tropical and sub-tropical parts of both Americas, from Texas to Argentine, except in arid and highly elevated districts. It is estimated that its annual damage to cultivated plants in the State of Sao Paulo alone is twenty-five million dollars, and in all Brazil, at least, two hundred and fifty millions. As practically only the coast strip of Brazil is at all thickly settled, while the great interior plateau and Amazonian forest regions are almost uncultivated, it is quite certain that the settled portion of the rest of humid tropical South America, comprised in the Guianas, Venezuela, Colombia, Ecuador, Peru, Bolivia, Northern Argentine and Paraguay, suffer an annual loss from the sauva double that of Brazil, or five hundred millions. Add to these figures the loss in the settled districts of the Central American Republics and Mexico, which certainly equals that of Brazil, and we find that the annual board bill of the sauva is easily one billion dollars. No other insect on earth can equal this.

"Tropical America and practically all of the Amazonian region, the most fertile and extensive warm agricultural region on earth, will one day feed the world's population. When that day arrives and the cultivated area is increased at least, a hundredfold throughout these countries, while productive capacity, due to more intensive systems of agriculture is further

increased tenfold to what staggering and incomprehensible figures will the sauva loss attain, if the pest is allowed to persist ? It is easy to realize in the face of this showing, that the sauva must be eliminated, if the agricultural interests of tropical America would come into their own."

Before taking up the experimental work a brief description of the distribution and habits of these ants might be of interest.

The leaf-cutting ants occupy a large territory. They are found in tropical and sub-tropical America from Texas to the Argentine in the low humid portions of the country. Species of these ants are also found on the islands of Cuba, Trinidad and Tobago. They are not known in the old world. The wide distribution of this pest has led to great variety of local names in the countries infested. Some of the more common names are Sauva in Southern Brazil, Formiga de Roco in Northern Brazil, "la hormiga Colorado" (ison) or (minera) and la hormiga negro in the Argentine. They are known as Fourmi Manico in French Guiana, Coushi ants in British Guiana, Parasolmieren in Suriname, Bibijagua in Cuba, Parasol ants and "Bachacks" in Trinidad, Pot ants in Tobago, Zompopo in Guatemala, and the Wee Wee in British Honduras.

The most important leaf-cutting ant of Brazil is determined as *Atta sexdens*. This species carries out extensive excavations resulting in the formation of large surface mounds. These mounds have been known to cover as much as a thousand square metres of surface and to extend in depth as far as eight or nine metres below the surface. Cases of nests so extensive that they have extended from one bank of a river, down under and up onto the other side are on record. The population of such nests has been estimated at from 175,000 to 600,000 individuals.

All nests begin with a single opening and food chamber. This is started by the queen after mating, which usually takes place early in December, in Brazil, when the ants swarm. After mating, the queen digs a hole into the ground and seals herself into a small chamber. Here she cultivates the fungus which she has carried in a pouch in her mouth from her old habitation. Upon the care and growth of this fungus depends the success of the new nest. As it grows the queen cultivates it in the shape of a dish in which she later lays her eggs. About fifteen days after the queen has started the nest

Fig. 18-4.—Excavated Nest of *Atta sexdens*. Showing Panellas.

the first eggs hatch. She cares for these young and feeds them on her own eggs until the fungus garden has made sufficient growth to fill the food requirements of the new colony. About forty days after the colony has started the first workers mature. A week later the larger workers develop and dig up to the surface and the enlargement of the colony has begun.

During the period in which the nest has not yet been opened to the surface those workers which have been hatched manure the fungus with their excrements and cultivate it carefully. As soon as the nest has been opened other types of workers go out to nearby trees for leaves. There are specially equipped cutter workers with sharp mandibles who climb up the trunks and cut out pieces of the leaves which fall to the ground and are taken up by others, whose sole job is to gather leaves and carry them to the nest.

Before beginning to gather leaves an entrance to the nest is made near the selected tree and a trail cleared from this entrance to the tree so that there will be an unimpeded path for their activities. Along this path is a continuous double line of ants, the one bearing leaves to the nest, the other returning to the tree for further material. If the

Fig. 19-4.—Enlarged Section of Nest Shown in Fig. 18-4.

pieces of leaves are too large to be taken into the entrance other workers from the interior of the nest come out and reduce them to small pieces, taking them into the nest where they are built up on the floors of the large nest chambers (panellas) into a spongy like mass upon which the food-producing mycelium is grown.

In the composition of a nest there are one or several queens, males, soldiers, and various types of workers which range from ordinary size down to the size of the head of a pin. Each caste has its own special function. The reproduction of the nest is taken care of by the queen and the males. The soldiers are equipped with fierce jaws and at any disturbance of the nest, flock out in swarms and attack any strange object near the nest. Each of the workers is fitted for its own type of work; some are leaf cutters, others porters, still others act as nursemaids to the larvae, licking and feeding them. There are gardeners who care for the fungus and other small ones whose function is to keep the nest clean. Some of the types of the workers never leave the nest.

The nests or ant hills vary in size from one cavity with a single opening to a large number of cavities with communicating passages and many entrances. The entrances are marked by little mounds called eyes or craters. The principal entrances lead down to the panellas (food chambers) and rearing rooms. The panellas are ordinarily about the size of a human head (Fig. 18-4) with a vaulted ceiling and a flat floor. The numbers of entrances of a single old nest have been known to exceed a hundred and fifty.

The damage that they do consists of the complete defoliation of economic crops of great value. This defoliation of crops usually takes place during the night or early morning. It is not uncommon for a man to wake up and find that nothing is left of his promising citrus grove but the leafless trunks and branches. (Fig. 20-4.) Their work is swift, methodical, and complete. Apparently citrus leaves are favorite garden supplies of these ants but they are also very fond of rose, cotton, and vegetable leaves. They never make raids upon coffee and tobacco and dislike such thick leaves as corn.

Dr. C. H. T. Townsend, while acting as entomologist for the state of Sao Paulo, conducted many experiments looking toward the control of the leaf-cutting ant. He early reached the conclusion that hydrocyanic acid gas was the one effective formicide. Carbon bisulphide, chlorine gas, the

Fig. 20-4.—Young Citrus Tree Defoliated by Leaf-Cutting Ants.

burning fumes of sulphur and arsenic, and sulphurous anhidride were all tried with but inferior results. From careful study he concluded that the slow diffusion, the fact that none of them were instantly toxic, and that all possessed an intensely repellant odor gave the ants a chance to escape either by blocking the corridors at the first warning or suspending their breathing by closing their spiracles until the material had become harmless by diffusion. On the other hand hydrocyanic acid possessed the desirable qualities for a perfect formicide. Being lighter than air and having a high molecular activity, it diffused rapidly in all directions, it had no warning odor, and was instantly toxic. Thus the ants were killed before preparations for escape could be made.

At that time the source of hydrocyanic acid gas was by generation from sodium cyanide and sulphuric acid. This would necessitate some arrangement whereby the gas could be generated outside the nest and then forced into it. Mr. James Zetek, in the Panama Canal Zone, had obtained a certain degree of success in destruction of ants by the use of solutions of sodium cyanide poured into the nest. This same method was being used with success on other species of ants. Experimental work

Fig. 21-4.—Tree in Same Grove not attacked by Ants.

indicated that hydrocyanic acid was a most effective formicide providing that an easy method of application could be devised. Cyanogas Calcium Cyanide as a convenient source of hydrocyanic acid gas appeared on the market at about that time.

Dr. Townsend used the flakes in his first work with Cyanogas. The method of application was very simple. As many holes as were located were enlarged and the flakes poured in and the holes closed with earth. Repeated experiments demonstrated the fact that the flakes were ineffective due to the fact that they could not be so placed that the liberated hydrocyanic acid gas reached all parts of the nest. It killed all ants with which it came into contact, but failed to reach all parts of the older and more extensive nests. At about the same time Dr. Stephen Bruner was obtaining similar results in Cuba for the control of the Bibijagua with Cyanogas Calcium Cyanide flakes.

Dr. Townsend's next experiments were aimed at the use of Cyanogas in the form of a dust. In the application of the dust one of the main openings of the nest was selected and into this the dust was forced by means of a suitable duster. Dust would then emerge from other openings of the nest. These openings were closed and the pumping was continued until a definite back pressure in the duster indicated that all of the communicating openings had been closed. Other openings from which dust had not emerged were then treated until dust had been pumped into or emerged from every opening in the nest.

Unfortunately the dust which had been shipped to Dr. Townsend was the old "C" Grade which contained 75% talc as a diluent. Even with this diluted form good results were obtained but it was necessary in the case of the older nests to treat them a large number of times before complete extermination could be obtained. He considered that the Cyanogas Calcium Cyanide was the most effective formicide that he had ever used for the control of the sauva.

In 1924 our Dr. E. D. Wilson and Mr. Frank Sheehy were sent to Brazil to develop the market for Cyanogas for the control of the sauva. It was then discovered that all the experiments had been conducted with the old "C" Grade instead of Cyanogas "A" Dust. It was therefore necessary to carry out experiments using "A" Dust to determine whether by the use of the stronger material, the number of treatments necessary for extermination in the case of old nests could not be reduced. The results of these tests are incorporated in Table II.

Tests against *Atta sexdens*, F. E. Sheehy–Brazil–1924 Table II

Expt. No.	Location	Date	Time	Weather	Soil	Material	Dose	Duster	No. of Treatment	Remarks
1	Santa Thereza	3/29	9:30 a.m.	Very warm	Dry & Hard	"A"	1 pound	Am. Beauty	1st	Nest not specially prepared, treatment incomplete. Number of dead ants at opening next day.
		3/30	10:00 a.m.	Slight Shower in afternoon	Dry & Hard	"A"	1 pound	Am. Beauty	2nd	Treated thoroughly—following day 2½ quarts found dead outside—many inside.
		3/31	3:00 p.m.	Slight shower in afternoon	Fairly Soft	"A"	½ pound	Am. Beauty	3rd	Nest killed—(Dr. C. Moreira says this nest the most difficult to kill that he has ever seen.)
2	Santa Thereza	4/5	2:30 p.m.	Warm	Dry	"A"	1½ pounds	Am. Beauty	1st	Nest small — nearly destroyed.
		4/7	9:00 a.m.	Warm	Dry	"A"	2 pounds	Am. Beauty	2nd	Killed out.
3	Paqueta	4/8	9:30 a.m.	Warm—slight showers late in evening of day before	Fairly hard	"A"	1 pound	Am. Beauty	1st	Ground cleared — dust pumped in for five minutes.
4	Paqueta	4/8	10:00 a.m.	Warm—slight showers late in evening of day before	Fairly hard	"A"	1½ pounds	Am. Beauty	1st	Pumped in until all holes were located and closed.
5	Santa Thereza	4/19	9:30 a.m.	Cloudy—day before slight rain	Damp	"A"	2 pounds	Am. Beauty	1st	Applied dust and dug out nest immediately—all ants dead.
		4/21	9:30 a.m.	Cloudy—day before slight rain	Wet	"A"	1 pound	Am. Beauty	2nd	New parts of nest located and dug out and dust pumped in.
		5/7	2:30 p.m.	Warm—slight rain day before	Moist	"A"	2 pounds	Am. Beauty	3rd	Openings showing activity treated and dug out all dead.
		5/12	10:00 a.m.	Warm	Fairly soft	"A"	½ pound	Am. Beauty	4th	New opening located and treated successfully.
6	Santa Thereza	5/12	9:30 a.m.	Warm	Fairly soft	"A"	1½ pounds	Am. Beauty	1st	Main opening cleared and treated—After several treatments killed out.
7	Santa Thereza	5/13	2:15 p.m.	Mild—rain during previous night	Soft	"A"	1½ pounds	Am. Beauty	1st	Entrance cleared—12 holes closed—Dust pumped for fifteen minutes.

Tests against *Atta sexdens*. F. E. SHEEHY–Brazil–1924 TABLE II—*Cont.*

EXPT. NO.	LOCATION	DATE	TIME	WEATHER	SOIL	MATERIAL	DOSE	DUSTER	NO. OF TREATMENT	REMARKS
		5/21	3:00 p.m.	Cloudy—rain day before	Damp	"A"	[illegible] pound	Am. Beauty	2nd	Very little activity—open holes treated with success.
8	Itaquaquecetuba	6/14	10:30 a.m.	Warm, slight shower day before	Damp	"A"	[illegible] pound	Am. Beauty	1st	25 openings–dust pumped in for one hour.
		6/14	2:30 p.m.	Warm, slight shower day before	Fairly Dry	"A"	¼ pound	Cyanogas	2nd	Nest dug out—those chambers that had been reached were killed.
9	Sao Paulo	6/18	10:00 a.m.	Warm	Dry	"A"	1 pound	Cyanogas	1st	Nest destroyed.
10	Sao Paulo	6/18	10:30 a.m.	Warm	Dry	"A"	1½ pounds	Cyanogas	1st	Treated for over an hour—dust emerged from twenty openings—Later treatments wiped it out.
		6/19	11:30 a.m.	Warm	Dry	"A"	1½ pounds	Cyanogas	2nd	
		6/20	9:30 a.m.	Warm	Dry	"A"	1½ pounds	Cyanogas	3rd	
11	Sao Paulo	6/18	11:30 a.m.	Warm	Dry	"A"	2½ pounds	Cyanogas Am. Beauty	1st	Three main holes treated—dust from more than 20 openings—some as far as forty feet away.
		6/19	2:30 p.m.	Warm	Dry	"A"	½ pound	Am. Beauty	2nd	Three openings active—treated.
		6/20	10:00 a.m.	Warm	Dry	"A"	½ pound	Am. Beauty	3rd	nest destroyed.
12	Campinas	6/25	3:00 p.m.	Warm	Dry	"A"	1 pound	Am. Beauty	1st	Treated for one-half hour.
		6/26	3:00 p.m.	Warm	Dry	"A"	1 pound	Am. Beauty	2nd	
		6/28	3:00 p.m.	Warm	Dry	"A"	1 pound	Am. Beauty	3rd	Nest destroyed.
		7/1	3:00 p.m.	Warm	Dry	"A"	1 pound	Am. Beauty	4th	
		7/4	3:00 p.m.	Warm	Dry	"A"	1 pound	Am. Beauty	5th	Nest dug out—destroyed.
13	Campinas	7/4	9:00 a.m.	Warm—day before mild	Dry & hard	"A"	½ pound	Am. Beauty	1st	Dust issued from 42 openings—nest destroyed.
14	Bells Horizonte	9/12	2:30 p.m.	Fairly warm	Very hard	"A"	¼ pound	Am. Beauty	1st	Nest caved in—impossible to treat well—
15	Bells Horizonte	9/12	3:30 p.m.	Fairly warm	Very hard	"A"	½ pound	Am. Beauty	1st	Poor application—
16	Rio de Janeiro	9/24	10:00 a.m.	Warm	Fairly hard	"A"	1 pound	Niagara	1st	
		9/25 9/27	9:00 a.m.	Warm	Fairly hard	"A"	Few oz.	Niagara	2nd	Only one opening active. One reopened passage treated
		10/4	[illegible]	Mild	Fairly [illegible]	"A"	[illegible] pound	Niagara	3rd	Concluded destroyed

Results of these experiments indicated that the ants in small nests could be easily exterminated but that several treatments were necessary for nests which had been established for many years. The necessity of repeated treatments was due to the extensive underground workings of the ants which made it very difficult for the gas to penetrate to all parts of the nest. The Cyanogas apparently poisoned the fungus, and any ants which survived the first treatment always endeavored to remove this poison'ed fungus from the nest. Later treatments would therefore reach deeper portions of the nest.

Another important point discovered was the presence of a draft thru the nest. It was found that there were certain holes with a strong internal suction. For instance, when a pump was held as far away as six inches from the entrance, all dust pumped into the air was immediately sucked down into the nest. It is not known whether this suction is limited to certain times of the day but it is plain that the ants so construct their nests that certain drafts, for fresh air supply, may occur.

Dr. C. H. T. Townsend's recent conclusions after five years work in extermination of *Atta sexdens* are here reproduced from an article entitled "Cyanogas Calcium Cyanide for the Control of *Atta sexdens L.* in Brazil", Journal of Economic Entomology, Vol. 18, No. 6, 1925, p. 840.

Cyanogas Calcium Cyanide for the Control of *Atta sexdens* L. in Brazil. Cyanogas Calcium Cyanide has for its base the chemical element nitrogen, extracted from the air by electric power generated at Niagara Falls in North America. Just two essential points need emphasis with regard to the use of Cyanogas in the extermination of the sauva. These are that:

(1) For more than 30 years hydrocyanic acid gas has been recognized as the most powerful and therefore the most efficient insecticide. During all this time nothing else has been able to compete with it, and it has consequently been employed in all cases where practicable. But it was not practicable to apply it to formigueiros with the pot method of generation by means of sulphuric acid, water and cyanide of soda, which for many years was the only method used in its production.

(2) Two years ago, when Cyanogas Calcium Cyanide was placed on the market, it first became practicable to apply hydrocyanic acid gas to the formigueiros, since Cyanogas generates this gas on being blown into the holes.

Some 25 years ago, when the use of hydrocyanic acid gas as an insecticide was comparatively new, Dr. Dafert, then director of the Instituto Agronomico of the State of Sao Paulo at Campinas, experimented with it against the sauva. In his report on experiments with all formicides known at the time, he stated that hydrocyanic acid gas is 100% efficient and no other formicide can compete with it, but he explicitly states also that he can not recommend its use on account of the danger attendant upon applying it. About 5 years ago, in a bulletin on sauva and the best known formicides, the writer, then with the Director of Agriculture of the State of

Note: Sauva—Leaf-cutting ant, *Atta sexdens* L. Formigueiros—Underground galleries or nest of *Atta sexdens* L.

Sao Paulo, stated that without doubt hydrocyanic acid gas would supersede all other formicides once a practical method was devised of applying it to the formigueiros. Cyanogas Calcium Cyanide was still unknown, but its appearance two years ago solved the problem of the practical and simple application of hydrocyanic acid gas to the nests.

With only ordinary precautions, there is absolutely no danger in the application of Cyanogas. The dust and the vapors given off by it should not be inhaled, the dust should not get into the mouth nor should it come in contact with skin abrasions. In the open air there is no danger of inhalation, in a closed space of humid air the handling of open tins of Cyanogas would be dangerous. In case of any effects arising from inhalation, the antidote is fumes of ammonia inhaled and artificial respiration if necessary. The writer has used Cyanogas Calcium Cyanide for two years without the slightest ill effect. Moreover, the Brazilians have long been familiar with this poison, for hydrocyanic acid gas is the active principle in the poisonous juice of bitter mandioca.

Full strength Cyanogas Calcium Cyanide is about 48 to 50% cyanide of calcium. It must be used in finely powdered or dust form for application to formigueiros, and the full strength or Grade "A" Dust should be employed for this purpose. Cyanide of calcium dissociates rapidly in the presence of moisture, whereas other cyanides do so only slowly. Cyanogas takes up the water from the humid air of the tunnels and panellas, while the cyanide content combines with this water to form HCN or hydrocyanic acid gas. The chemical reaction is as follows:

$$Ca(CN)_2+2H_2O=2HCN+Ca(OH)_2$$

Which is to say that 1 molecule of calcium cyanide combines with 2 molecules of water to form 2 molecules of hydrocyanic acid gas and 1 molecule of slaked lime.

For many decades numerous patented formicides have been placed on the Brazilian market, each manufacturer claiming not only superiority but infallibility for his product. Each one of these has been tried in turn by the fazendeiros without securing decisive results. In every case it has been found necessary to continue applications year after year, practically never securing extinction of the formigueiros. Therefore the Brazilian fazendeiro has become skeptical with regard to new formicides and is indifferent to the claims made with regard to them, naturally believing all to be more or less alike and none to be capable of exterminating the sauva. For this reason it has been necessary to give demonstrations with Cyanogas Calcium Cyanide free of charge on the largest and most important properties in order to prove the exterminating efficiency of the product, and its immense superiority over all other formicides. Once this superiority becomes generally known, there is no doubt of Cyanogas superseding all other preparations as a formicide.

Hydrocyanic acid gas is nearly the same weight as the warm humid air in the nests of the sauva. Furthermore, due to its high molecular activity, it readily permeates and mixes with the air in all directions, up, down, or laterally, throughout all communicating spaces. That it is not heavier than air is an advantage in its use, since a heavy gas would settle to the bottom of the nests and dissipate rapidly through the soil.

The greater part of the hydrocyanic acid gas is formed immediately the Cyanogas Calcium Cyanide dust is blown into the nests, but the reaction continues for some 24 to 48 hours until the process is complete. The nest is thus continuously filled with the gas for sufficient time to kill out any ants that may happen to be outside the nest at time of treatment, for, on returning and attempting to dig in, these ants will

breathe the gas and die. Hydrocyanic acid gas kills the larvae of the ants as well as the adults. It also kills the fungus on which the ants feed, either directly or by removing the ants whose duty it is to care for it. The larvae resulting from any eggs that may hatch after the treatment of a nest die for lack of food and ants to care for them. The extermination of the formigueiro is thus complete. All that is necessary is that the gas reach every part of the formigueiro so that all the ants get one full breath of it.

The amount of Cyanogas Calcium Cyanide required to fill a given formigueiro with hydrocyanic acid gas varies according to the cubic capacity of the tunnels and panellas. It may be stated that, on the average, ten minutes work with the small Feeny duster will use ¼ kilo of Cyanogas. Large old nests of 100 or more openings may require 40 minutes and use 1 kilo of Cyanogas. The largest nests with very extensive communications will require still more. New nests of small extent will require only ⅛ to ¼ of a kilo. Neither water nor fire are to be used in the application of Cyanogas Calcium Cyanide yet the dust issues from communicating holes like a black smoke just as if fire were being used. This property is an absolute necessity in the application of any gas to sauva nests, in order that communicating holes may be located, recognized and closed.

No cleaning of formigueiros preparatory to treatment is necessary other than to cut away matto sufficiently to introduce the tube of the blower into the holes. The less a nest is disturbed before treating, the better will be the results of the treatment. It is important to overlook no holes at the first treatment, in order to secure speedy extinction of the nest. The largest holes should be selected first for treatment, meantime closing all holes from which the smokelike dust issues. The blower should be worked in each hole, from which no smoke has issued, until a pronounced air-compression is felt. Some holes in very large nests may be treated as long as 20 minutes before getting this air-compression, while only a few seconds of treatment will show it in others. Compression indicates that all communicating passages and panellas are well filled with the gas, and the treatment should be then transferred to other holes. But the caution must here be given not to plug either the holes or the tube of the blower with earth while introducing the tube into the holes. Treated nests should be observed daily and all holes found open must be promptly treated and closed. Such application of Cyanogas, carefully carried out, will completely exterminate the nest, and the length of time required for extermination will depend on the experience and technique of the operator and the thoroughness of application without missing any holes.

The best time of year to secure speedy extermination of formigueiros is just before the swarming time, which period varies from September to December according to localities and conditions. At this time excavations are not in progress and the ants are all assembled in the upper parts of the nest attending the broods of queens and drones that are being developed preparatory to swarming.

Charles H. T. Townsend

LEAF-CUTTING ANTS—GUATEMALA

At the same time that work was going on in Brazil, Cyanogas Calcium Cyanide was being successfully used in Guatemala against the Zompopo. An account of this early work has already been reproduced herein on page 4-49, from the "Boletin de Agricultura, Industria y Comercio."

LEAF-CUTTING ANTS—TRINIDAD

The following note on the Parasol Ant of Trinidad and Tobago is taken from an article by Mr. F. W. Urich, F.E.S., C.M.Z.S., Government Entomologist, in the "Bulletin of the Department of Agriculture of Trinidad and Tobago." It indicates, in a general way, the peculiarities of these two insular species.

"Parasol Ants"

"Under this heading two species of leaf-cutting ants are dealt with *Atta cephalotes* or the "Bachack" and *Atta octospinosa* or the "Parasol Ant" of Trinidad and the "Pot Ant" of Tobago.

"Bachacks (*A. cephalotes*) are the most injurious species and are generally found on cacao estates and uncultivated land bordering them, they live in large communities in the ground and a so-called nest consists of a collection of small chambers connected by tunnels. If left undisturbed a nest will persist for many years and will gradually expand until it may cover quite a large area. Nests from sixty to twenty feet across are of common occurrence. All nests, however, begin with one chamber and one exit hole. Large nests have from fifty to sixty exits, but as a rule not all are used by the ants.

"The ants are reddish brown and "soldiers" are always present. The queens are darker than the workers and measure about one inch in length; workers or foragers vary in size from one-eighth to three-fourths of an inch. Stiff clay soils are preferred by the ants.

"Parasol or Pot Ants (*A. octospinosa*) do not live in communities like the Bachacks and the nest generally consists of one chamber in the ground. These ants also make use of any cavities in walls, under rotten logs of wood, tubs, and flower pots; provided moisture conditions are suitable they will take advantage of any dark and quiet corner in field or garden.

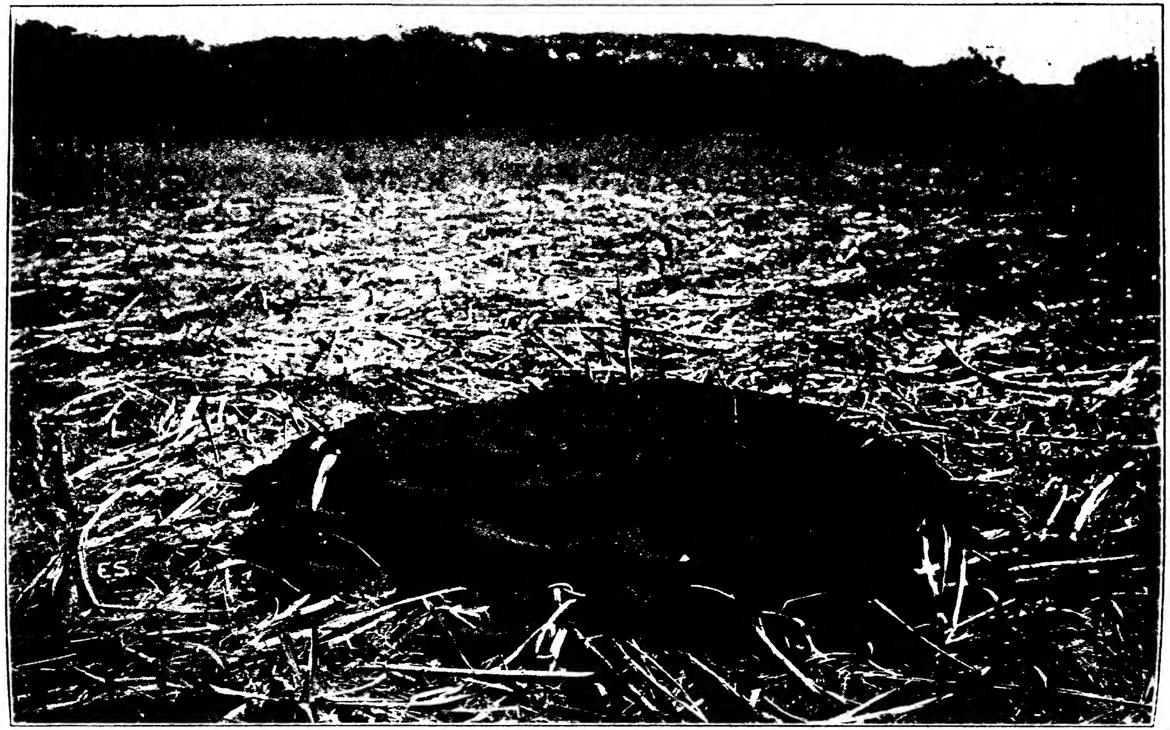

Fig. 22-4. Nest of *Atta insularius*. Bibijagua. (Ants in this nest were completely exterminated with one treatment (less than ½lb. Cyanogas "A" Dust applied by means of a large foot-pump).

TABLE III.

Atta cephalotes (Urich–Trinidad)

No. of Nest	Area in Sq. Ft.	First Application Date	First Application Particulars	Area per Ounce	First Inspection	Second Inspection	Later Inspections	Total Area per ounce	Remarks
1	144	25/4/24	4 oz. calcium cyanide placed in main entrance blown slightly and covered—very dry weather.	36 sq. ft.	11 days after dead ants at entrance. Reclosed.	7 days later—no signs of activity		36 sq. ft.	19/7/24 dead
2	80	25/4/24	2 oz. applied as above.	40 sq. ft.	as above	as above.		40 sq. ft.	19/7/24 dead
3	160	25/4/24	2 oz. applied as above.	40 sq. ft.	as above	as above.		40 sq. ft.	19/7/24 dead
4	192	25/4/24	2 oz. applied as above.	48 sq. ft.	as above.	as above.		48 sq. ft.	19/7/24 dead
5	360	6/5/24	2 oz. applied as above.	60 sq. ft.	6 days after—holes open.	9 days later—pumped in 4 oz.		36 sq. ft.	19/7/24 all dead
6 7 8	266	21/5/24	4½ oz. applied with duster.	59 sq. ft.	5 days later—found open.	12 days after: 6—all dead 7—all dead 8—open			19/7/24 all dead
9	1,260	26/5/24	4 oz. with dust pump	315 sq. ft.	5 days later—some active.	7 days after—pumped in 10 oz.—weather somewhat damper	2 oz. and 2 applied subsequently—weather very damp	70 sq. ft.	19/7/24 very much weakened but still active
10	648	26/5/24	8 oz. with dust pump in thoro manner—damp weather, altho sunny.	81 sq. ft.	3 days after—many open and active.	Weather became damp meanwhile—3 days after pumped in 4 oz.	2 oz., 4 oz., and 4 oz. applied subsequently—more or less wet—application on sunny days	29 sq. ft.	19/7/24 slightly weakened, but still much alive
11	460	6/6/24	6 oz. pumped in—weather damp.	76 sq. ft.	10 days after some holes open—4 oz. pumped in very damp.			46 sq. ft.	still alive and fairly active

Fig. 23-4. Work of *Atta octospinosa* in Trinidad

Parasol ants are not of much importance on estates, they are more injurious about gardens. The queens are half an inch long and reddish brown in color; there are no "soldiers" and the workers vary from a little over a quarter to one-eighth of an inch in length.

"The two species differ in feeding habits; *Atta cephalotes* seems to confine itself mostly to leaves, but *Atta octospinosa* will take flowers of different kinds in addition to young leaves as well as the skin of ripe cocoa pods."

Mr. Urich has performed some experiments with Cyanogas Calcium Cyanide "A" Dust against *Atta cephalotes*, a summary of which is included in Table III. The nests of this species are of such a simple character that extermination was secured by merely throwing the material down the entrances.

Similar successful experiments against *Atta* spp. have been conducted in Suriname, Mexico, San Salvador, and the Panama Canal Zone. The method of procedure and the results are essentially the same as those in Brazil. At the present time an extensive series of experiments against *Atta insularis*

(Bibijagua) of Cuba are being conducted by Dr. Stephen Bruner of the Estacion Experimental Agronomica at Santiago, our Mr. Bromley cooperating.

The objects of the experiments in Cuba is primarily a study of the exact distribution of dust in the nests by means of various types of dusters. Although these experiments are not yet completed the indications are that a foot pump is more effective than a rotary type of duster. A sketch of a treated nest, indicating distribution of the dust when applied by means of a foot pump, is shown in Fig. 24-4.

EXPERIMENTS IN THE ARGENTINE

Altho species of the genus *Atta* occur in the Argentine, there is another leaf-cutting ant commonly known as the black leaf-cutting ant, *Acromyrmex lundi*, which is particularly interesting in that it constructs a nest which is different in type from the typical *Atta* nest.

The dirt which is excavated in construction of the nest is scattered over a considerable area about the nest, making a low inconspicuous mound over which the grass never stops growing. The entrances of the nest are relatively small and are usually obscured by overhanging grass. The runways within the mound run straight down for about 20 or 30 cm. Here they become larger in diameter and run completely around the single large food chamber. The food chamber consists of a spherical cone lined completely with a mass of twigs, which usually vary in thickness from 5 to 20 cm. Usually an air space is found between the twig mass and the top of the earthen cave. Within this twig lining, a single large spongy mass of fungus gardens is located in which the eggs are laid, the young reared, and the food cultivated.

Runways of unknown purpose lead down below the nest and are usually filled with dead ants and debris. There seem to be other cavities or wide places in the runways in which are deposited the freshly cut leaves. These latter often play an important part in plugging up a run, since the draft created in the treatment will drive them out into the runway and when in quantity will stop the flow of dust and form a plug.

In 1924 our Mr. Frank E. Todd carried out a number of experiments in the Argentine against the black leaf-cutting ant. Tests were made with both flakes and Cyanogas "A" Dust. After a nest had been treated it was dug out in order to determine the exact behavior of the formicide.

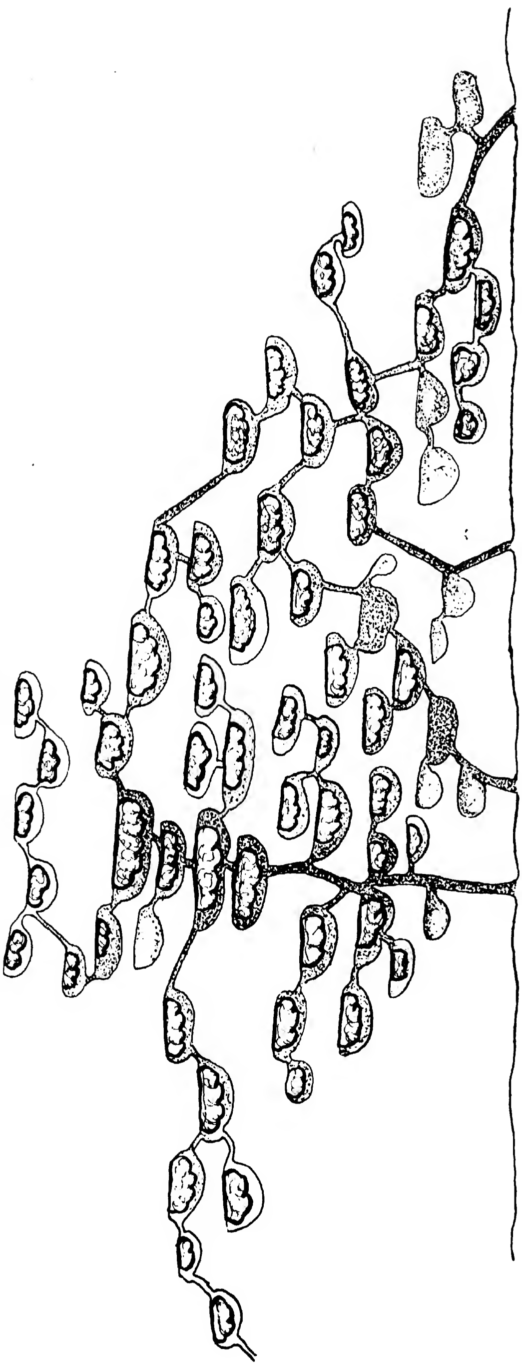

Fig. 24-4.—Distribution of Cyanogas "A" Dust, by Means of a Foot-Pump, in a Bibijague Nest (Stippling indicates presence of dust.)

These subsequent excavations showed that the dust pumped into the central entrances was quite likely to plug up before reaching the larger runways. As the larger runways which circled the food chamber were but a spades depth from the outside holes it was better to dig down and treat such holes on opposite sides of the nest so that all parts could be reached in case one side should be plugged by debris in the corridors.

The nests of this species were too extensive to be controlled by pouring flakes down the entrance hence their use was abandoned in favor of Cyanogas Calcium Cyanide "A" Dust, applied with a duster. Experiments of the same character, carried on by our Mr. George G. Wittwer in 1925, have confirmed the earlier conclusions that it is possible to destroy permanently nests of *Acromyrmex lundi*.

CYANOGAS DUST TREATMENT OF NESTS OF THE LEAF-CUTTING ANT (*ATTA SEXDENS* AND RELATED SPECIES)

1. Cut away all growth around the nest to make the openings visible and accessible. Care should be taken not to disturb any of the holes or to block them with dirt.

2. Insert the delivery tube of the duster tightly into the main openings of the nest and pump the Cyanogas dust into the nest. After the dust has issued from other openings of the nest for a short time they should be plugged with dirt. Continue pumping until dust no longer issues from any opening of the nest and a pronounced air compression is felt. Remove the delivery tube, close the hole, and insert the delivery tube into any other opening from which dust has not issued. Continue the treatment as outlined until the dust has been driven into or has issued from every opening of the nest.

3. Observe the nest daily and if any new holes appear treat them.

These details, carefully followed, will secure the complete destruction of the nest. The most favorable time for treatment is during the month before swarming, when the ants have ceased their excavations and are congregated in the upper levels of the nest with all the tunnels clear of obstructions.

Several treatments may be necessary to destroy completely a nest at other times of the year. The failure to destroy the entire colony at these times is usually due to blind burrows

or blocked tunnels, which cause an air compression in the lower levels and prevents the dust from reaching all parts of the nest. If the treatment is made just before swarming, failure is solely due to overlooking some of the holes, which thus escape treatment.

ADVANTAGES OF CYANOGAS METHOD

1. No special preparatory digging to prepare the nest for treatment is necessary, except in the case of the black leaf-cutting ant, thus saving much time and labor.

Fig. 25-4.—Applying Cyanogas to a Bibijagua Nest by Means of a Small Hand Duster.

2. The hydrocyanic acid gas is superior in killing effect to all other gases.

3. Cyanogas "A" Dust dissociates much more rapidly in the presence of moisture than any other dry cyanide preparation, giving off its hydrocyanic acid practically at once.

4. The ants reached by the gas die immediately and are thus unable to block their burrows to prevent the passage of the gas.

5. Communicating holes are revealed by the issuance of a smoke-like dust making it unnecessary to seek out and treat each opening.

6. Stoppage of holes is revealed by an increased air pressure, while the absence of obstructions and the presence of escape holes is determined by the lack of air pressure in working the bellows.

7. The cost of extinction of the nests in time, labor, and materials is lower than with any other material.

HARVESTER ANTS

The harvester ants are found in the sub-tropical regions; apparently being most numerous in the arid districts. They obtained their name from the fact that they dig up and carry away seeds which they store in their nests. They will even invade granaries and barns in search of seed. Some species make very large mounds in and under which the nest is found (Fig. 26-4). Others have their nests underground with only a little loose dirt around the entrance at the surface.

Experiments have been conducted for the control of harvester ants in Arizona, Oklahoma, Kansas, Texas, Florida, and in the northwest. *Pogonomyrmex occidentalis* is the species generally known as the mound building harvester ant. The most comprehensive experiments for the control of this species were carried out by our Mr. I. L. Ressler in Kansas. Holes were made in the mound to a depth of three or four feet, the number made depending upon the size of the mound. A soil auger was found to make a clean hole without plugging the passages of the nest with soil. Each hole was then treated with a half ounce of Cyanogas Calcium Cyanide G-Fumigant. It was found wise to check up about fifteen days later in order to be sure that the colony had been exterminated.

In Arizona, it was found that where the soil was very hard, the best results could be obtained by using a slow burning blasting powder in conjunction with the Cyanogas. Holes were made in the mound with a soil auger and the blasting powder placed in the bottom and covered with soil. The fuse was lighted after the Cyanogas had been placed in other holes and covered. The explosion loosened the soil slightly and allowed the gas to penetrate to all parts of the nest. Of five large nests so treated by our Mr. Bromley, but one ever showed any signs of reinfestation.

Working with a species of harvester ant which did not build a mound, our Mr. R. G. Eidson found that good results might be obtained by placing the Cyanogas directly in the entrance of the nest. His experiments were carried out in Florida.

The stinging ant, *Solenopsis geminata,* is also classed as a harvester ant, due to the fact that it sometimes collects seeds. It has quite a wide range of activity and destruction. It is known as the Stinging Ant in Trinidad, the "Hormiguilla" in Porto Rico, the Red Ant in Mauritius and the Phillipines, and the "Little Brown Ant" in Texas. They are very annoying

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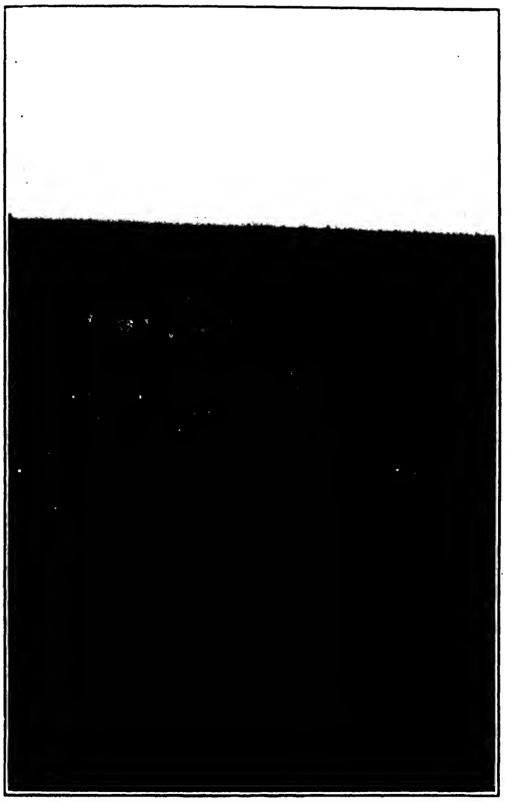

Fig. 26-4.—Nest of the Western Harvester Ant.
(6 feet in diameter.)

garden pests since they encourage and foster other destructive insects, such as scale insects, mealy bugs, leaf hoppers, and plant lice, and feed extensively on plant roots. The nests, which are built in the ground, have galleries running out to the roots of plants where the ants feed on the soft tissues or place their protege insects to feed. The presence of a nest is readily detected by a mound of earth piled up at the base of the plant.

In the lower Rio Grande valley of Texas, this ant is one of the most destructive pests of the citrus groves. In the autumn and winter after the crops raised between the young citrus trees have been removed these ants attack the trees eating the tender bark and leaves. A method for the control of this species was worked out by our Mr. Stirrett. Fifty acres of one-year-old grapefruit trees were treated. The nests were located,

uprooted with a hoe, and a small amount of Cyanogas "A" Dust blown over them. The trunk and larger limbs of the tree were also sprinkled with the dust, using about two ounces per nest.

Professor Urich in Trinidad worked out a method of control similar to that in Texas. His directions are summarized as follows:

1—When ants are numerous dust both the plants and ants lightly with Cyanogas "A" Dust. The foliage of the plants should be dry.

2—When ants are at the roots break up the earth around the plant and dust.

3—Trace nests in the ground, destroy all parts, and dust.

OTHER MOUND BUILDING ANTS

A large red ant (unidentified) is often destructive in the orchards of the northwestern part of the United States. The method of treatment is very simple. A stick is poked into the mound, the Cyanogas applied, and the holes left open. This method is most effective.

For many years the destruction of forest trees and nursery plantation stock, particularly evergreens, by the mound building ant, *Formica exsectoides,* went more or less unnoticed and hence uncontrolled until the increased value of the crop made it necessary to use some method of control. The satisfactory results obtained with Cyanogas Calcium Cyanide are included in the following report by Prof. J. A. Manter of the Storrs Experimental Station, Storrs, Connecticut, which is reproduced from the Journal of Economic Entomology, Vol. 18, No. 2, April, 1925, p. 348.

A PRELIMINARY REPORT ON THE USE OF CALCIUM CYANIDE FOR THE MOUND BUILDING ANT, *FORMICA EXSECTOIDES*

By J. A. Manter, *Storrs, Conn.*

The mounds or "ant hills" built by *Formica exsectoides* are quite well known to observers in the Northeastern United States. They are found in pasture and open spaces in woodland. Trees or high bushes are never found in close proximity to these mounds because the ants kill off any growth that might shade their nest. This injury to forest trees

was not recorded as of importance until 1912. Several investigators since that time have studied the problem and Peirson in 1922 published[1] the results of his studies in which he showed how the ants were able to kill trees. The usual material recommended for the control of these ants is carbon disulphide. During the past summer I have used several insecticides, including calcium cyanide, to bring about the extermination of certain colonies of these ants working in forest plantations at the Connecticut Agricultural College. I believe that calcium cyanide will prove to be a practicable remedy.

Injuries to Trees

The killing of trees by these ants is most noticeable and injurious in forest plantations and natural reproduction of evergreens. It is common to find cleared areas around these mounds from 24 to 36 feet in diameter in which there is no plant growth higher than about two feet. Outside of these nearly circular areas the stand of trees and bushes may be normal. The contrast between the growth inside and outside of these circles is very marked.

Early investigators believed that the ants were responsible for the death of the trees but could not explain how it was done. Fungi were commonly found but were not proven to be the causative organisms. Peirson discovered ants in the act of "squirting" formic acid into wounds that they had made in the bark. He shows that the acid coagulates[1] the cell protoplasm and thus causes a cessation of the downward flow of the sap causing the ultimate starvation and death of the tree. Both conifers and deciduous trees may be killed but the former are more susceptible to injury I have observed their work in plantations of red and white pines, red and scotch pines, and of white spruce. At first the ants chew off some of the bark from the lower part of the trunk completely encircling it and extending a foot or more above the ground. This allows the formic acid to reach the living cells of the bark. Trees above eight feet are not often killed, probably because their thicker bark prevents the formic acid from reaching the living cells. Dead white pines show a deep constriction encircling the trunk a little above the ground with a marked swelling just above. This enlargement is caused by the continued growth made possible by the piling up of the sap at this point. On white spruce the constrictions and swellings are not so prominent The poisoned bark becomes loosened after a few years and breaks away from the wood. The first evidence of injury to a healthy tree is a gradual yellowing of the needles on the new growth.

[1] H B. Peirson, Journal of Forestry, Vol. XX, No. 4, April 1922.

Ants have been considered of benefit in woodland since they destroy large numbers of other insects for food but the damage done by *exsectoides* places it among the harmful forest pests. It is not uncommon for a colony of these ants to kill from 30 to 40 young evergreens about their nest. In a 6′ x 6′ triangular planting of one acre, a cleared circle of 36 feet about a mound will include 37 trees, which accounts for nearly 3 per cent of the total stand. Ant hills may average several to the acre. One observer records the killing of 75 per cent of a small plantation of white pine.

Control

Carbon disulphide, if used liberally, will kill the ants of a colony. The method of treatment is to make holes in the mound 8 to 10 inches deep and about the same distance apart and pour into each 1 or 2 ounces of carbon disulphide. An average sized colony requires one pound or more, and for effective work the mound must be covered with a tub, wet burlap bags, or some other material. This method is costly, requires considerable labor, and a relatively high atmospheric temperature.

Calcium cyanide in the granular form has been used in these trials with very promising results. The method has been to make holes in the mounds as before, putting a small amount of the cyanide into each and filling with dirt. Two ounces for an average sized mound seems to be sufficient. No cover for the mound is necessary. Cyanide spread on top of the mound was not effective.

It is surprising to see how quickly the ants are killed when they come near this material. After seeing its deadly effect on insect life one is prompted to handle it carefully. I think the carbide odor given off by this crude cyanide serves as a warning that should help to prevent accidents. When treated mounds were dug into, some of the galleries were found crowded with the dead bodies of the ants. Usually a few living stragglers could be found. It is perhaps, too much to expect that all of the thousands of ants of a colony would be killed at once because some of them might have been away at the time of fumigation. The real test of the effectiveness of any method of control is the killing of the brood and queen as without these the rest of the colony dies. The cyanide method is not expensive. It can be applied quickly, as no special covering of the mound is necessary, and a high temperature is not needed for the production of the gas.

Fig. 27-4.—Widening Entrances of Harvester Ant Nest with a Soil Auger.

ANTS ON LAWNS AND GOLF GREENS

Some of the earliest work in the control of the more common species of ants found on lawns was carried out in Indiana by our Mr. Curtis Benton. He used Cyanogas Calcium Cyanide "A" Dust and also the coarse Granular material in his experiments against various unidentified species of lawn ants. Some of the results of his work are included in Table IV.

In treating ant nests on golf greens the problem is more difficult since the green is usually covered with a very tender grass. To be successful the treatment must destroy the ants without any injury to this grass. It was felt, in view of the various preliminary experiments which had been performed, that a very fine granular material which would flow like sand into the ant nests would give the best results. Cyanogas Calcium Cyanide G-Fumigant seemed to fit this requirement.

TABLE IV.

Ant	Cyanogas Calcium Cyanide	Rate of Application	% Kill	Remarks
Large black	Granular	¼ ounce	100	Damage to grass because wet
Small red	Granular	⅛ ounce	90	Slight damage to grass
Small red	A Dust	1¾ ounces	75	Seven holes treated
Small red	Granular	6¼ ounces	98	50 holes treated—no grass burn
Small red	Granular	2½ ounces	98	10 holes treated—no grass burn
Large red	Granular	½ ounce	100	No injury to grass
Small red	Granular	¼ ounce	100	No injury to grass
Small red	A Dust	1 ounce	50	4 holes treated—no grass injury
Small red	A Dust	1¼ ounces	60	5 holes treated — no grass injury

Our Mr. Stanley W. Bromley carried out a series of experiments at the Merion Cricket Club Golf Course, Ardmore, Pennsylvania. Preliminary survey showed that several species of small ground-nesting ants were abundant. The green was watered and rolled the evening before the tests were begun July 31, 1924. Cyanogas G-Fumigant was used in these experiments. Table V shows the dosage, description of nest treated, and the results.

The little injury that occurred was located at the edge of the mounds and it was difficult to decide whether this was due to the effect of the Cyanogas or previous activity of the ants.

Fig. 28-4.—Lawn Ants Killed with Cyanogas.

Table V.

No.	Type of Entrance	Application and Dose	Observation of Effects Aug. 2, 5, 10	
			Grass	*Insects*
1	Fair size nest	1 pinch in opening–closed	No injury	Killed
2	Smaller nest—no grass within 1″	Open'ng widened 1″ depth —entrance closed	No injury	Killed
3	Medium nest—no grass nearer than 1½″	2 pinches mounded over top	Some injury	Killed
4	No grass within 1″	2 pinches washed in with water	Some injury	Killed
5	No grass within 1½″	3 pinches—soil packed in opening	Slight injury	Killed
6	No grass within 1″	1 pinch	No injury	Killed
7	Grass within 1″	1 pinch washed down with water	Some injury	Killed
8	Grass within 1″	2 pinches—soil packed in entrance	Slight injury	Killed
9	Grass within 1½″	2 pinches—nest closed	Slight injury	Killed
10	Grass within 2″	3 pinches—soil packed in entrance	Some burning	Killed
11	Grass at entrance	1 pinch nest closed	Some burning	Killed
12	Grass at entrance	2 pinches—nest closed	Some burning	Killed
13	Grass at entrance	1 pinch—nest closed	Some burning	Killed
14	Grass within 2″	3 pinches—Soil packed in opening	Slight injury	Killed
15	Grass within 1″	3 pinches—nest closed	Some injury	Killed
16	Grass within 1½″	3 pinches—nest closed	Some injury	Killed
17	Grass within 2″	1 pinch—nest closed	Some injury	Killed

From these experiments the following procedure was recommended:

1—It is best to work with the soil damp.

2—For the larger nests, where the grass is 1½ or 2 inches from the entrance, a pinch of Cyanogas G-Fumigant deposited in the entrance will be very effective in destroying the colony and very little injury to the grass will result.

3—In case of the larger nests, it is not necessary to widen the entrances.

4—For the smaller nests, a small stick or pencil should be used to make a hole into the nest after which a pinch or two of Cyanogas is poured in by means of a small funnel. The opening is then pinched shut.

5—Go over the treated area, ten days or so later, to treat entrances overlooked or nests not entirely exterminated.

6—Care must be taken not to allow the Cyanogas G-Fumigant to fall on the grass.

7—Do not use water to wash the Cyanogas into the nest as it may cause injury to the grass.

The Cyanogas Calcium Cyanide Treatment for the Cuban Leaf-Cutting Ant

By
S. C. Bruner, Cuban Agricultural Experiment Station, Santiago de Las Vegas, Cuba; and S. W. Bromley, New York City.

INTRODUCTION

The Cuban Leaf-Cutting Ant or Bibijagua, *Atta insularis* Guerin, is unquestionably one of the most generally destructive insect pests occurring on the Island. Effective and economical means of control have been sought for many years, without entirely satisfactory results.

STRUCTURE OF THE NESTS

The habits of this ant are similar to those of other species of this genus. It constructs large underground nests, furnishing the chambers with leaves of various plants which form the substratum for the fungus on which the ants subsist. It is this leaf-cutting habit, of course, which is responsible for its destructiveness as it uses, to a large extent, leaves of valuable plants such as orange trees for this purpose.

The nests usually consist of a very large series of chambers excavated at various depths below the surface of the soil. In some cases, particularly in the younger nests, the upper chambers may be situated only one or two feet from the surface; but in the typical soil of western Cuba the majority are usually at a level of from 3 to 6 feet, although some may extend to greater depths. These chambers normally have vaulted roofs and flattened bottoms and are level or occasionally somewhat inclined. They measure from 3 to 8 inches in height by 4 inches or more in length; and are usually elongated in outline, although the smaller ones are often rounded. Each chamber is provided with from two to four entrances, at least one of which is in the bottom near one side and the other in the top; additional openings may be in the sides. Some of the small chambers appear to have only one entrance. The chambers are connected with one another and with the outlets directly above by an intricate system of more or less tubular galleries.

As has been pointed out by Dr. Wheeler (Bul. Am. Mus. Nat. Hist., XXIII, Article XXXI, Sept., 1907, p.p. 669-807.) for the species *Atta texana* Buckley, it is probable that the majority of the craters situated directly above the nest are

constructed for aeration and not for entrance and exit. However, in the case of *Atta insularis* some are used for this purpose as the ants have not infrequently been observed carrying in plant material through these openings. Other galleries are constructed by the ants for their foraging expeditions. These extend outward in horizontal directions from the center of the nest for considerable distances at a depth of several feet.

Only one mother queen or fertile female is found in each nest of the Bibijagua. This also seems to be true of other species of *Atta*. It is not always a simple matter to locate the queen by excavating the nests. In one treated nest, carefully dug out, one was found dead in the center of a fungus garden 5½ feet below the surface. The object of the treatment should therefore be primarily directed towards killing the queen if a colony is to be entirely destroyed.

PRELIMINARY WORK WITH CALCIUM CYANIDE

Tests for the control of the Bibijagua with Cyanogas Calcium Cyanide were begun in 1922. This material was then available only in the form of flakes of irregular size sold under the name of "Gas Flakes" which were, except in form, essentially the same as the Cyanogas Calcium Cyanide produced today, liberating hydrocyanic acid gas, the killing agent, on contact with atmospheric moisture. A number of nests or "bibijagueros" of different sizes were treated, the material being introduced into the more important openings directly above the brood chambers. The whole area treated was then covered as quickly as possible with one or more pieces of tarpaulin, which were held down around the edges to prevent the escape of the gas by covering with loose earth. A number of nests of small or medium size were killed by this method, but satisfactory results could not always be obtained. Failure usually resulted in the case of larger nests, the reason being that the diffusion of the gas was evidently not sufficient to penetrate to the lower levels and kill the insects in these chambers.

Some time later Cyanogas Calcium Cyanide in granular and dust form was introduced. As the granular material was composed of smaller particles than the flakes it could be more easily introduced into the galleries, "flowing" downward for a considerable distance. It was found that by treating and covering all of the more important openings within the central area of a "bibijaguero" it was possible to kill those of small and moderate size, sometimes with a single treatment.

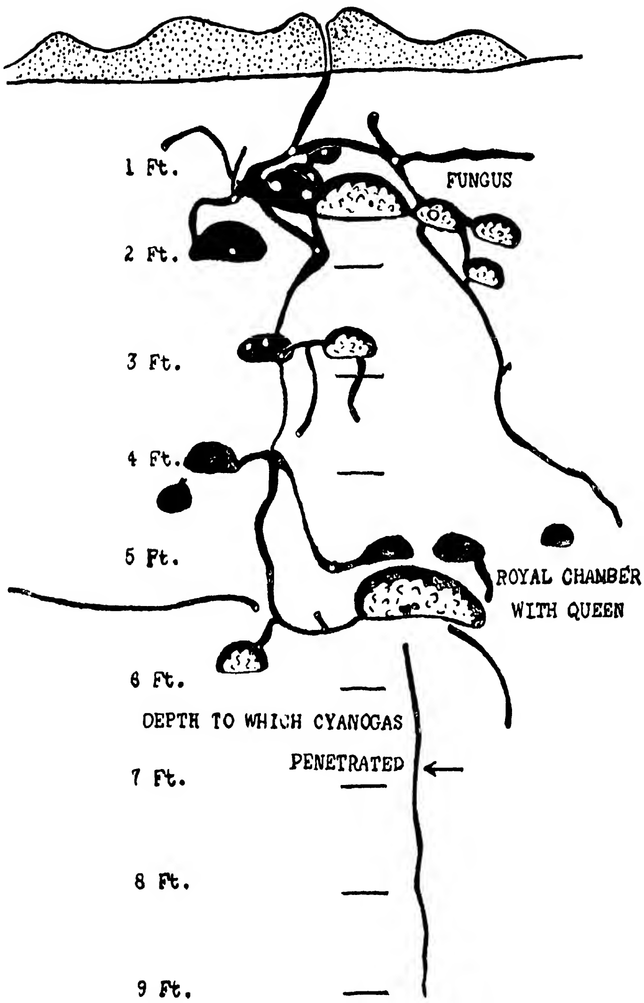

Fig. 29-4.—Section of Part of a "Bibijaguero". The Small Light Spots in the Chambers Indicate Entrances of Other Tunnels.

Not infrequently, however, a second or even a third treatment was required. One half to one ounce of the material was generally applied in each opening.

USE OF HAND AND KNAPSACK TYPE OF DUSTERS

It was realized that a better distribution of dust throughout the nest could be obtained if a blower or dust gun were used. Accordingly, tests were made at the Cuban Experiment Station with such small hand dusters as were then available. These did not prove satisfactory. In 1924 Mr. W. J. Murphy of the American Cyanamid Co., visited the Station and introduced several types of hand dusters and the American Beauty Knapsack duster for this purpose. These were tested but found to be only partly effective for the smallest nests and although the larger bellows duster gave rather good results with one or two applications it was not designed for the work intended and, on the whole, was not satisfactory.

TESTS DURING 1925-26

In November, 1925, tests were begun, using the foot-pump type of duster which was developed for rat control by means of calcium cyanide in the United States.

Various other methods were also tested. Simply placing the dust in openings without the use of a blower was found unsatisfactory as the larger nests could not be killed by this method nor was it entirely satisfactory for small bibijagueros. The granular material gave much better results when so applied. Treatment of nests with an aqueous solution was soon abandoned as, due to the exceedingly porous nature of the soil a very large amount of water was required to reach all parts of the nest, which greatly increased the cost and time required for the treatment. One large colony was treated with 5 pounds of "A" dust in 30 gallons of water, one gallon being poured into each of the 30 principal openings, which were then closed with earth. This treatment was not sufficient to kill the colony which resumed activity after two weeks.

RESULTS OBTAINED WITH FOOT-PUMP TYPE OF DUSTER

The use of the specially designed foot-pump for applying the Cyanogas Calcium Cyanide dust was found to give the best results of any method tested. This machine holds 3½ pounds of dust and is operated on the principle of a bicycle pump, the machine resting on the ground and the dust blown

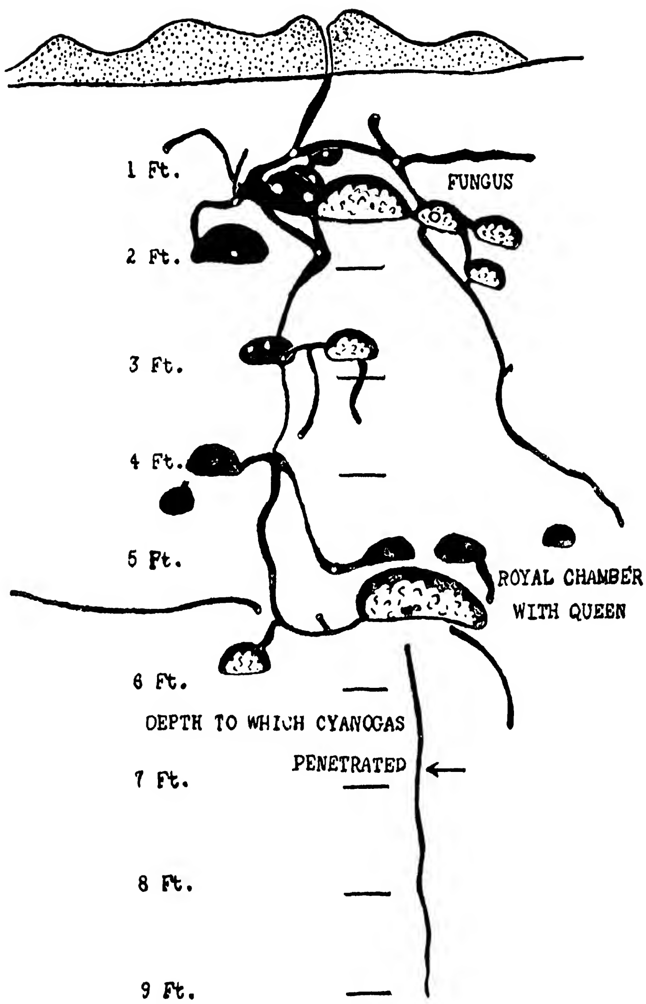

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Fig. 30-4.—Treating a Bibijagua Nest With Cyanogas Calcium Cyanide "A" Dust by Means of a Foot Pump. Note That the Mounds Above the Nest Have All Been Cleared Away.

into the burrows through a flexible metal tube. This was much more satisfactory than either the small hand dusters or the bellows type dusters previously tested, due to the greater ease of application and the greater pressure obtained. The only disadvantage experienced with this type of pump was the fact that dust was not delivered uniformly. When the pump was full, a heavy cloud of dust was forced out with each stroke, but as the operation progressed the volume of dust delivered gradually diminished even though the pump was half-filled. To remedy this, it was found necessary to simply invert the duster at intervals during the treatment to prevent packing. As the duster seemed to work best when full, it was considered advisable to keep the chamber filled with dust rather than wait until empty before refilling.

TYPES OF CALCIUM CYANIDE TESTED

Several types of Cyanogas Calcium Cyanide were tested. The first was the granular form previously mentioned which, although evolving the gas over a longer period of time, could not be applied with the duster. The other types were in the form of dust, one being the so-called "A" dust, and the other bearing the trade name of "Citrus Dust," which contains 25% of dusting sulphur. Most of the experiments, however, were conducted with the "A" dust.

MOST SATISFACTORY METHOD OF APPLICATION

As a result of the numerous tests made, the following method of treating the bibijagueros was found to be most satisfactory. Two or three days prior to the treatment the mounds and surrounding grass or bushes were cleared away. This not only facilitated the work of locating and treating all openings, but insured the treatment of the more important ones which are naturally the first to be reopened by the ants. The actual treatment consisted of blowing the dust into all of the more important openings in order to thoroughly saturate the chambers and kill the queen, whose exact location was of course unknown. Experience has shown that the best procedure is to select a large opening which is then treated for about five to ten minutes, providing no back pressure develops. The smoke-like dust will issue at once from the nearest more directly connected openings, which should then be closed with earth. Other openings are treated successively in a similar manner until all are closed. There no doubt occurs a considerable absorption of the gas by the moist walls of the tunnels and for this reason the dust rather than the gas should penetrate all parts of the nest. While the treat-

ment of the central area is of primary importance it is well to treat a number of the lateral openings in order to insure the thorough saturation of all confines of the colony. By so doing, dust may be forced into some of the lower chambers which might not have been reached by the treatment of the central nest area, due to the fact that the dust when applied to these lateral openings does not have to pass through many fungus chambers, which might act as a filter.

TIME OF TREATMENT AND DOSAGE REQUIRED

The time required for treatment varies greatly according to the size of the nest. Ordinarily from one half to five pounds of the dust are necessary for one treatment. It was found that about fifteen minutes were required to apply one pound of the dust by means of the large foot-pump previously mentioned. Although it was often possible to completely kill nests of small or moderate size with one treatment, large nests generally required a second and sometimes even a third. If the queen is not killed but the majority of the workers are, it may be a week or more before there are signs of activity. For this reason it is necessary to inspect the nest one or two weeks later and thoroughly treat all openings. This should kill all survivors. In other cases the queen may be killed but a considerable number of the workers survive. We have treated nests and a day or two later noticed activity at a few openings. These became more feebly worked as the days went by until finally all activity ceased. In such instances the queen was no doubt killed and the remaining workers continued to attend the fungus gardens least affected by the treatment until they died out.

CONCLUSIONS

In conclusion, it might be said that the results obtained on this species were substantially the same as those obtained in Brazil on *Atta sexdens* by Dr. C. H. T. Townsend (Cyanogas Calcium Cyanide for the control of *Atta sexdens* L. in Brazil, Journal of Economic Entomology, Vol. 18, No. 6, 1925, p. 840) except that the larger foot-pump types of dusters were found to be better adapted to the treatment of the nests than the small type of duster used in Brazil. In other words, method and thoroughness of treatment can be considered the most important factors in the destruction of the colony. The point to be kept in mind is the extermination of the queen and a majority of the workers to insure the destruction of the nest.

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RATTENBESTRIJDING MET CALCIUMCYANIDE

door

Dr. V. J. KONINGSBERGER.

Degeen die, na wat er in den laatsten tijd in het „Archief" omtrent de meening van enkele deskundigen over rattenbestrijding werd overgenomen, hetzelfde onderwerp weer aan de orde stelt, wordt gedrongen tot een uiteenzetting waar, wanneer en hoe hij dezen hardnekkigen cultuurvijand wil bestrijden.

De geneeskundige medewerker van de „Nieuwe Rotterdamsche Courant" (Archief 1926, I p. 394 e.v.) geeft als zijn, op tal van autoritaire uitspraken van anderen gebaseerde, meening te kennen, dat directe bestrijding van ratten in steden nooit afdoende zal kunnen zijn om de plaag zichtbaar te doen afnemen. Hoogstens zal deze bestrijding een hulpmiddel kunnen zijn, naast de eenige afdoende bestrijding: de stad zoo in te richten, dat zij voor ratten alle attractie verliest. Met andere woorden gezegd: de bouwhygiëne, de zindelijkheid en de afvoer van afvalstoffen moeten zoodanig worden georganiseerd, dat de stad onbewoonbaar wordt voor ratten, die er noch verblijfplaatsen noch voedsel kunnen vinden. Dit betoog is logisch en heeft er vermoedelijk toe bijgedragen, het nog labiele evenwicht te dezer zake bij de hygiënisten te stabiliseeren.

Ik wil het dan ook niet hebben over de rattenbestrijding in steden, maar over die in het open veld, waar jaarlijks kapitalen aan Europeesche en Inlandsche landbouwproducten aan deze knaagdieren ten offer vallen. Het is duidelijk, dat de situatie hier anders is. Is het in de steden mogelijk, de bereide producten van landbouw en veeteelt zoodanig op te schuren, dat zij practisch voor ratten onbereikbaar zijn, iedereen zal moeten toegeven, dat dit met de te velde staande gewassen, i.e. het voedsel van de veldrat, anders is gesteld. Geen hygiënische maatregelen zijn hier in staat deze goede gravers, zwemmers en klimmers het leven onmogelijk, of zelfs maar zuur te maken.

Wil men dus iets tegen de rattenplaag te velde doen, dan blijft er niets anders over dan de directe bestrijding.

Ook in dit geval zijn velen omtrent mogelijk succes sceptisch gestemd. In bovenbedoelde artikelen werden twee moderne middelen besproken: ratin en ratinin; het eerste een bacteriepreparaat, het laatste een maagvergif. De bezwaren tegen deze middelen worden uitvoerig besproken, en rattenkenners bij uitnemendheid, het echtpaar Dr. HAGEDOORN, zetten hun, eveneens weinig hoop gevende meening uiteen. (Archief 1926 I, p. 352). Tegen de slotconclusie uit dit alles, overgenomen door het Proefstation (Archief 1926 I, p. 394) „dat principieel van *deze* bestrijding in een land als Java nooit iets te verwachten is", zijn geen doorslaande argumenten aan te voeren. Ook ratinin is behept met de bezwaren, die tegen elk maagvergif zijn aan te voeren; de ratten krijgen spoedig verdenking, zij mijden het vergiftigde aas en waarom zouden zij dat niet doen, waar overal ander voedsel is te krijgen. Bovendien levert elk maagvergif het gevaar op in een andere maag terecht te kunnen komen, dan waarvoor het bestemd is.

De schrijvers gaan echter verder: zij achten goed gelezen, iedere succesvolle bestrijding onmogelijk. Deze uitspraak wordt gebaseerd op de leerstelling: „In bepaalde omstandigheden fokken ratten eenvoudig zoo voort, dat de bevolking evenredig is aan den bereikbaren voedselvoorraad". Zoo eenvoudig is het nu niet: hier wordt een zeer speculatieve hypothese als uitgangspunt hunner redeneering aanvaard. Voor de juistheid hiervan ontbreekt ieder bewijs. Ik wil daar theoretisch niet diep op ingaan, dach slechts enkele aanvechtbare punten aanduiden. In de eerste plaats is op tal van plaatsen op Java de voedselvoorraad nimmer een beperkende factor voor de verdere voortplanting van ratten en toch is ook daar het aantal ratten niet onbegrensd groot.

Verder wordt een overdreven waarde gehecht aan de groote vruchbaarheid van ratten voor het snelle herstel van het vroegere evenwicht, i.e. het oorspronkelijk aantal ratten. Daarbij wordt vergeten, dat ieder gedood paar in de meetkundige reeks, waarin de opeenvolgende geslachten zich samenvoegen, de getallen met denzelfden factor doet dalen, als zich vermenigvuldigende ratten haar doen stijgen. Hieruit volgt dat de vermenigvuldigingsfactor des te minder invloed heeft, naarmate het oorspronkelijk getal grooter is geweest en in ons geval mogen we gerust aannemen, dat het zéér groot is.

Er wanneer ten slotte Dr. HAGEDOORN, na jarenlang onderzoek tot de uitspraak komt: p. 307. „Door studin van rattenschade in

rijst en suiker op Java, is ons duidelijk gebleken, dat uitroeien ondoenlijk is, maar dat in de practijk slechts helpt een verandering van de levensomstandigheden van de dieren", zou ik de vraag willen stellen of de bestrijding zelf niet onder „veranderde levensomstandigheden" moet worden gerekend. Volgens den schrijver niet: „het vangen, doodslaan, vergiftigen van 99% van de rattenbevolking is voor de practijk even weinig afdoende als het jaarlijksche wegschieten van iets minder dan de natuurlijke aanwas van konijnen en fazanten door een zorgvuldigen jachteigenaar". Evenmin volgens het Proefstation dat zegt: (l.c. p. 394): „dat principieel van deze bestrijding in een land als Java niets te verwachten is, daar de vermeerderingssnelheid in verband met de aanwezige voedselvoorraad een zoodanige is, dat het vernietigen van een aantal exemplaren slechts zeer tijdelijk een gering effect kan hebben".

Wanneer hiermede bedoeld wordt een incidenteele bestrijding, zooals deze in den regel wordt toegepast, namelijk alléén als men last van ratten ondervindt, moet men de juistheid van deze zienswijze inderdaad toegeven.

Hiermede kom ik op het voornaamste punt, dat buiten beschouwing bleef: wat verstaat men feitelijk onder „bestrijding": waar en wanneer moet deze worden toegepast? Op deze vraag luide het antwoord: een succesvolle bestrijding is slechts mogelijk door altijd en overal te bestrijden.

Het is duidelijk, om tot de 99% vernietigde dieren van Dr. HAGEDOORN terug te keeren, dat men niet weer 100% van het oorspronkelijke aantal krijgt, als de overlevende 1% en nakomelingschap weer voor 99% wordt gedood, voordat 10% van het uitgangsgetal bereikt is. Dan houdt men 0,1% over. Wordt dit wéér met zijn nakomelingschap vernietigd, voordat het zich 10 maal heeft vermenigvuldigd, dan houdt men 0,01% van het oorspronkelijk aantal over.

Bij een voortdurende bestrijding altijd dóór, wijzigt men inderdaad de levensomstandigheden, men schuift de grens der bestaansmogelijkheid terug; het aantal moet verminderen. Of de werkzaamheid van den mensch of een onnatuurlijke toename van het aantal katten daar de oorzaak van is, is onverschillig: het natuurlijk evenwicht in de natuurlijke rattensamenleving wordt verstoord en verlegd.

Mits daarbij wordt bedacht, dat de bestrijding niet hier en daar plaatselijk moet worden toegepast, doch over heele aaneengesloten gebieden.

Dr. Hagedoorn schrijft (l.c. p. 306) „op een enkele suikerfabriek werden dagelijks (ten minste twee jaar lang) tusschen negen en elfduizend ratten doodgeslagen en voor de premie binnengebracht" en vervolgt, dat dit absoluut geen vermindering ten gevolge had.

Hier heeft Dr. Hagedoorn zich een peroratorische vrijheid veroorloofd, of de betrokken suikerfabriek heeft zich door premiejagende koelies, die van heinde en verre met ratten kwamen aandragen, beet laten nemen. Zoo eenvoudig en constant is de jaarlijksche verspreiding van de ratten-standaard niet.

Wij laten hieronder een tabel volgen van het aantal ratten, dat door een West-Cheribonsche en een Pemalangsche fabriek werd gedood.

Maanden :	Per plantjaar gevangen ratten		
	West-Cheribon		Pemalang
	1924 — 1925	1925 — 1926	1924 — 1925
Maart	7437	3130	—
April	14955	9022	32055
Mei	22655	38651	283329
Juni	30723	29270	112843
Juli	29506	23761	99784
Augustus	20537	11197	321681
September	15076	28884	328069
October	17842	27153	137808
November	24636	20845	opgehouden
December	36363	4311	—
Januari	25952	11191	—
Februari	16716	9662	—
Maart	10746	11398	—
April	14085	327	—
Totaal	284229	128802	1315569

In de maanden Mei en Juni zien wij de eerste groote invasie optreden, wanneer het jonge riet voor ratten aantrekkelijk schijnt te zijn. Een andere groote invasie pleegt op te treden in den tijd der zware bandjirs, hetgeen uit de West-Cheribon cijfers 1924—1925 (November—Januari) duidelijk blijkt. In dat jaar heeft DI 52 op die onderneming en ook elders in die streek een zeer gevoelige schade geleden.

Merkwaardig genoeg is van die invasie in het laatste jaar op deze onderneming, in tegenstelling met de buurfabrieken (Januari — Maart), bijna niets te merken geweest.

Uit deze cijfers volgt, dat de ratten niet als „gezeten" fauna mogen worden beschouwd, maar dat zij, al naar hun voedsel- e.a. omstandigheden meebrengen, zich nu in het riet, dan in de padi, enz. ophouden. Noch bestrijding in de riettuinen, noch die in de sawah's alleen kan helpen, een fabriek moet in haar geheele areaal bestrijden en dit zal nog weinig baten, indien de buurfabrieken zulks nalaten.

Het ligt m.i. op den weg van de cultuurvoorlichting, om hier eens met nadruk op te wijzen. Wat toch is het geval? Háár standpunt is, dat incidenteele bestrijding niets geeft, maar de practijk voelt zich niet verantwoord, wanneer zij niets tegen dit schadelijk gedierte doet. Zij bestrijdt dus toch, doch slechts incidenteel, zoolang zij namelijk last van ratten ondervindt.

Hier wordt oneconomisch gewerkt, want gesteld al, dat men met hooge bestrijdingskosten een nog grootere schade tijdelijk heeft kunnen voorkomen, de bedreiging van een nieuwen aanval blijft als een zwaard van DAMOCLES boven den aanplant hangen, niet alleen voor nu, maar ook voor volgende jaren.

De redeneering van den bedrijfsleider is hier: „zoodra ik last van ratten ondervind en de schade met cijfers kan aantoonen, wenscht mijn Directie, dat ik daar wat tegen doe en zijn de uitgaven dus verantwoord". Terecht wordt door het Proefstation hiertegen stelling genomen, maar een andere weg is, voor zoover mij bekend, nimmer aangewezen. Men krijgt hieruit den indruk, dat de voorlichtingsdienst van oordeel is, dat men zonder meer in het kwaad moet berusten.

Ik meen in het bovenstaande den weg te hebben aangeduid, om de landbouwproducten, die jaarlijks door de veldrat worden geconsumeerd, toe te voegen aan onzen oogst, namelijk door een voortdurende en overal toegepaste bestrijding. Ik wil daar aanstonds de bezwaren van de practijk tegen dit systeem aan toevoegen. Eigenlijk komen deze neer op het omgekeerde van zooeven: „wanneer ik blijf doorgaan met het bestrijden van ratten, als deze geen schade meer aan mijn aanplant toebrengen, ben ik tegenover mijn Directie niet verantwoord, daar niet met cijfers aangetoond kan worden, dat ik daardoor verdere schade voorkom."

En hiermede sluit zich deze vicieuze cirkel. Want bijna niemand durft, ook al neemt hij de juistheid dezer redeneering aan, zijn „géld wegsmijten voor een zichtbaar schijnsucces" te verwisselen voor „geld uitgeven voor een althans vooreerst onzicht-

baar succes". Eerst moet de schade er zijn, dan pas worden fondsen gevonden om het kwaad te bestrijden. Op deze wijze loopt men achter de feiten aan zonder deze ooit volledig te achterhalen of ongedaan te maken.

Feitelijk doet zich in de kwestie der boorderbestrijding precies hetzelfde voor. Het is de verdienste van den Heer POLL (Archief 1925—1926) dat hij in verschillende artikelen pleit voor een bestrijding, als hier bedoeld en wij twijfelen er niet aan, of het „vooreerst onzichtbaar succes" zal op sf. „Kalibagor" merkbaar worden na een hardnekkig voortgezette, permanente bestrijding.

In een permanente, preventieve bestrijding ligt het voornaamste, weinig bekende en nog minder erkende streven van de moderne phytopathologie c. a. Het geld daaraan besteed, is te beschouwen als een soort verzekeringspremie, waarvan het nut zich niet van te voren laat voorspellen.

In den regel gaat men er pas toe over, die premie te betalen na een ernstige catastrophe; zoo betaalt men nu steeds in de bibitvoorziening grif de premie om zich tegen een sereheatastrophe als die van de '80-er jaren te dekken.

Of, om een voorbeeld te noemen, waaraan deze mededeeling haar oorsprong ontleent: in Australië wist het daar niet inheemsche konijn zich na invoer, bij afwezigheid zijner natuurlijke vijanden, tot zulk een vlucht te ontwikkelen, dat het een bedreiging werd voor den landbouw, zoo ernstig, dat de bestrijding sedert eenige jaren van Gouvernementswege ter hand werd genomen en voorloopig met succes, sinds de toepassing van calciumcyanide.

Het is dit middel, dat ik hieronder bij de Java-Suikerindustrie wil introduceeren, waartoe het eerstens worde vergeleken met de tot dusver gebruikelijke bestrijdingsmiddelen. Deze kunnen alle in drie categoriën worden ondergebracht.

I. *het vangen van ratten met honden en koelies*. Dit systeem wordt toegepast door die ondernemingen, die voortdurend de veldrat bestrijden. De betaling geschiedt zoowel in dagloonen als in premies. Een voordeel is, dat men een goede contrôle heeft op de werkzaamheden. Deze methode kan echter nooit volkomen succes opleveren door de eraan verbonden nadeelen.

   1. de methode is zeer tijdroovend en kostbaar [1]) (openslaan der holen).

[1]) Volgens verstrekte nauwkeurige opgaven varieert het bedrag per gevangen rat van 0,92 tot 12,01 cent. Hoe grooter het aantal ratten, des te geringer zijn de kosten per gedoode rat.

2. bij het openslaan der holen, krijgen de volwassen ratten veelal gelegenheid te ontsnappen, voornamelijk jonge, nog niet geslachtsrijpe dieren worden gedood.
3. bij het afnemen van het aantal ratten wordt de bestrijding moeilijker. Vooral de op premies werkende koelies verliezen den prikkel tot het opsporen en openslaan der nesten of zij halen de ratten van elders.

II. *maagvergiften e.d.* (waaronder te rekenen bacterie- en serumpreparaten). Hiermee bereikt men hoofdzakelijk volwassen dieren. Nadeelen:
1. spoedig krijgen de dieren argwaan tegen het aas en mijden dit. Men moet het aas voortdurend van aard en samenstelling doen wisselen, wat omslachtig en kostbaar wordt.
2. men bereikt slechts de toevallig het aas passeerende dieren.
3. gevaar voor andere dieren, o.a. kleiner vee, geiten e.d.

III. *ademhalingsvergiften.* Als voordeel hiervan moet gerekend worden, dat men alle dieren, groot en klein, in hun holen, de schuilplaatsen van overdag, bereiken kan. Tot dusver waren alle ademhalingsvergiften echter met groote nadeelen behept. Vele middelen (o.a. zwavelkoolstof) zijn te duur en/of te langzaam werkend. Andere werken zeer snel, maar leveren tevens gevaar op voor dengeen, die ermede werkt. Hiertoe behoort blauwzuurgas, dat onmiddellijk werkt en veelal gebruikt wordt voor de ontratting van schepen. Het omgaan met de (tevens moeilijk transporteerbare) generatoren bleek echter zeer gevaarlijk voor de inheemsche werkkrachten.

Tot deze laatste middelen nu behoort ook calciumcyanide. Het is een product van de „American Cyanamide Company" te New-York, het concern, dat de Niagara-vallen exploiteert voor het binden van luchtstikstof, voornamelijk tot kalkstikstof (calciumcyanamide). Het wordt afgeleverd in verschillende assortimenten, die alle een bepaald percentage cyaankalk (Ca $(CN)_2$) bevatten.

Het grootste voordeel nu van dit middel is, dat men wel met blauwzuurgas (HCN) vergiftigt, doch de „generator" van dit gas, d.w.z. de stof, waaruit het gas zich ontwikkelt, zelf in een nog ongevaarlijken vorm in het hol brengt.

Onder invloed van den atmosferischen waterdamp, die in de holen vrijwel steeds de verzadigde spanning nadert, krijgt men de volgende omzetting:

$$Ca\,(CN)_2 + 2H_2O \rightarrow 2\,HCN + Ca\,(OH)_2.$$

Een ander buitengewoon voordeel springt uit deze vergelijking naar voren: na de gasontwikkeling blijft slechts een volkomen onschadelijk product: gebluschte kalk, achter.

Wij laten hier thans de resultaten van eenige proefnemingen volgen. Wij ontvingen twee assortimenten, nl. „granular", een grofkorrelig product, dat eenvoudig met een langgesteeld lepeltje in het hol wordt gegooid en „A-dust" een zeer fijn poeder, dat met een pulverisateur in het hol moet worden geblazen.

Het „granular" materiaal werd o. a. toegepast op sf. „Soerawinangoen". Op 29 Maart werden in mijn tegenwoordigheid proeven genomen. In de eerste plaats om de letale dosis en de snelheid van werking te beproeven. Men had in een kuil van 2 voet diepte een aantal ratten verzameld, t.w. 1 volwassen, 5 halfwassen en 10 nog zeer jonge ratten. In den kuil werd ongeveer 1 gram cyaankalk gebracht. Binnen één minuut was de volwassen rat dood, de halfwassen ratten waren bewusteloos doch vertoonden nog heftige spierkrampen. De jongste ratten liepen nog rond. Na vijf minuten bleken ook de halfwassen ratten dood, de jongste slechts bewusteloos. Er werd thans nog een gram toegevoegd en na 10 minuten was alles dood.

Hoe onder de ratten zijn, dit bleek ook in alle verdere proeven, des te eerder worden zij gedood. Intusschen bleek ook, dat bewustelooze dieren, zelfs al worden zij dadelijk in de frissche lucht gebracht, zich niet weer herstellen. Zij gaan zonder uit de narcose te ontwaken, onder hevige spierkrampen, vooral van de ademhalingsorganen, onherroepelijk te gronde.

Bij de verdere proeven werd met een Z.A.-lepeltje ongeveer 3 gram cyaankalk in een hol gebracht, de opening oppervlakkig met aarde gesloten en na eenige minuten het hol opengeslagen. Steeds bleek het succes volkomen. Een enkele maal wist een volwassen rat door een anderen uitgang te ontkomen, viel echter terstond neer, om onder de boven beschreven verschijnselen spoedig te sterven. Soms bleek een hol niet door ratten bewoond, maar door een slang, die het uiteraard ook had afgelegd.

Het andere materiaal „A-dust" werd ter proefneming aan sf. „Kadipaten" afgestaan, met een pulverisateur, zooals deze in Australië bij de konijnenbestrijding wordt gebruikt. Dit toestel een z.g. „dustblower" werd mij door de firma BUZACOTT & Co. Ltd. uit Sydney toegezonden en werkt zeer goed, terwijl een automatisch bepaalde dosis voor ieder hol wordt verbruikt. Het toestel is echter voor ons doel minder geschikt; het is te groot om in de riettuinen te worden

getransporteerd en feitelijk te zwaar voor één koelie. Bovendien lijkt de constructie te zwak voor datgene, wat zij van onze koelies hebben te verduren. Het ontwerp van een ander toestel is bij ons reeds in bewerking.

Intusschen bleek mij, bij mijn bezoek op 28 April, de werking nog veel sneller te zijn, het resultaat wederom volkomen. De behandeling is echter iets omslachtiger.

Op beide ondernemingen werden de holen opgespoord met honden, zooals die op deze ondernemingen bij de rattenjacht worden gebruikt. Bij het openslaan van een met „granular" behandeld hol, wist een hond erbij te komen, snuffelde even aan het hol en kon slechts met moeite weer bij worden gebracht. Bij „A-dust"-proeven was een even onvoorzichtige hond onmiddellijk dood.

Wij vermelden dit om te wijzen op het groote gevaar van het ontijdig openslaan der holen. De koelies hebben daar een zeer sterke neiging toe, omdat zij niet kunnen begrijpen, dat een beetje van dit poeder zoo vernietigend werkt. Zij willen zich aanstonds van het „wonder" overtuigen en gedragen zich daarbij even onvoorzichtig als bedoelde honden.

De *voordeelen* resumeerende, noem ik

1. de bijzonder eenvoudige toepassing, vooral van „granular",
2. de zeer snelle en feillooze werking,
3. de geringe kosten door de kleine dosis; nagenoeg geen transportkosten, geen tijdverlies —mits men het openslaan der holen verbiedt.
4. het *droge* poeder is voor het gebruik ongevaarlijk; alleen wanneer het in aanraking komt met open wonden is het zeer vergiftig.
5. de gevaarlijke blauwzuurdampen ontwikkelen zich ondergrondsch.
6. onschadelijke, gebluschte kalk is het eenige achterblijvend bestanddeel.

Bij een goed georganiseerde toepassing staan hiertegenover geen nadeelen. De mogelijke gevaren zijn gemakkelijk te ondervangen; zij ontstaan alleen bij onvoorzichtigheid.

Zoo moet worden bedacht, dat in den westmoesson de dampkring zeer vochtig is; de bussen, waarin de cyaankalk wordt bewaard en vervoerd moeten goed sluiten. Bij het gebruik van „granular" moet dan snel worden gewerkt; de bussen moeten zoo kort mogelijk geopend worden. Gedurende regens dient het gebruik te worden verboden.

Een ander gevaar schuilt, zooals gezegd, in het ontijdig d.w.z. te vroeg openslaan der holen. Naar mijn meening bereikt men daar niets mede en dient dit eenvoudig te worden verboden. Ik heb dit reeds voorgesteld, doch mij werd toen geantwoord, dat men dan geen contrôle op de koelies heeft. Dit is wel waar, maar de graad van juistheid dezer contrôle weegt m.i. niet op tegen het enorme tijdverlies verbonden aan het opengraven der holen.

Eén koelie, die niets anders te doen heeft, dan elk — eventueel met behulp van een hond gevonden — hol te vergeven, doet oneindig veel méér af, dan een groepje van drie of vier koelies, die ieder hol moeten uitgraven (na minstens 10 minuten wachten) en het gat weer dichtwerpen.

De laatste methode kost niet alleen een veelvoud van de eerste, maar levert tevens het nadeel op, dat dagelijks een veel kleiner areaal wordt behandeld, met als gevolg, dat men na veel langere tusschenpoozen op dezelfde gronden terugkomt.

Naar mijn inzicht dient de rattenbestrijding zoodanig te worden georganiseerd, dat de onderneming haar geheele areaal zóó over een aantal „Cyaangas"-koelies verdeelt, dat elke koelie ten minste iedere twee maanden in zijn gebied weer op dezelfde plaatsen terugkomt. Deze menschen hebben niets anders te doen dan het hun toegewezen gebied, al dan niet met behulp van een hond, af te zoeken en aan ieder hol cyaankalk toe te dienen en dit oppervlakkig af te sluiten. Zij beperken hun werkzaamheden niet tot de riettuinen maar zoeken overal, dus ook in de sawah's, dessa's enz.

Het spreekt van zelf, dat wij hier slechts een schema geven, dat al naar de omstandigheden door de practijk automatisch wordt gewijzigd. Daarbij moet tevens proefondervindelijk blijken, hoeveel volk men noodig heeft.

Men bedenke dat in het begin, zelfs bij te werkstelling van veel koelies, elke gedoode rat practisch niets kost, omdat er zoo verbazend veel worden gedood. Nu spreekt het van zelf, dat bij het afnemen van het aantal ratten, de kosten per gedoode rat sterk oploopen. Hoe hooger deze kosten worden, m.a.w. hoe minder ratten gedood worden, des te beter effect heeft de bestrijding.

Iedereen voelt, dat dit theoretisch juist is, maar dat de practijk eischt, dat er een redelijk evenwicht ontstaat tusschen bestrijdingskosten en kosten per gedoode rat. Vangt men practisch niets meer dan *houde men niet op, maar vermindere zijn „cyaangas-staf" zoodanig, dat men dezen toestand handhaaft.*

Het is duidelijk dat ook hierom een zekere contrôle wenschelijk is. Men late daarom op ongeregelde tijden de koelies contrôleeren en daarbij kunnen dan tevens nu en dan holen geopend worden, om een indruk te krijgen van de grootte van het aantal ratten.

Op den voorgrond sta, dat men nimmer de bestrijding geheel stake, ook al komen practisch geen ratten meer voor en dat men de bestrijding niet tot de riettuinen beperke.

Iedereen weet dat de rattenschade aan het riet slechts een fractie beteekent van de schade aan de padi. Een bestrijding, als hier bedoeld, is dus zéér sterk in het voordeel van de inlandsche bevolking. In deze streken wordt dat door haar ook zeer goed ingezien en acht ik het zeer waarschijnlijk, dat men van dessa-wege bereid blijkt het door de fabriek verstrekte materiaal verder toe te passen. Zoo acht ik het, zonder daarover in détails te treden, in vele gevallen mogelijk om met de bevolking tot een compromis te geraken, zoodat de bestrijding van dezen gemeenschappelijken vijand geen al te zware, ja zelfs geen zware kosten op de fabriek laadt.

Terloops moge worden opgemerkt, dat dezelfde cyaankalk alle dierlijk leven doodt, zonder de plant ook maar in het minst aan te tasten. Zoo laat het middel zich met groot succes tegen engerlingen-, termietenplagen e.d. aanwenden. In landen met „white labour" gaat men nog verder, door het te gebruiken tegen bovengrondsche dierlijke vijanden als luizen, rupsen e.d., maar dat lijkt ons h.t.l. gevaarlijk, of men moest daarbij gasmaskers met basisch nikkelcarbonaat of natriumthiosulfaat laten dragen.

Wat engerlingenplagen e.d. betreft, zijn wij inmiddels gaarne bereid tot het verstrekken van nadere inlichtingen.

De „cyano-gas"-producten der „American-Cyanamide Company" zijn nog niet op Java verkrijgbaar. Wel werd dezer dagen, naar aanleiding onzer geslaagde proefnemingen, de Internationale Crediet- en Handelsvereeniging „Rotterdam" door den fabrikant tot vertegenwoordiger voor deze producten op Java benoemd.

Onderafdeeling CHERIBON, Juni 1926.

Translated from the Dutch—"Archives of the Sugar Industry of the Dutch East Indies" 1926, No. 26, pp. 669-679.

Controlling Rats With Calcium Cyanide

By Dr. V. J. Koningsberger.

Coming back to the subject of rat control concerning which several articles have appeared in the "Archief", I shall show how and when this terrible plague can be controlled.

The medical correspondent of the "Niewe Rotterdamsche Courant" (Year 1926, I, p. 394 1st Vol.), on the strength of numerous authorities, expresses the belief that the direct control of rats in cities can never be sufficiently and positively effective. At most this control can only be auxiliary to some other means of control, namely that the cities be so built as to lose all attraction for the rats. In other words, building sanitation, cleanliness, and refuse disposal must be so organized that the city will be uninhabitable for the rats which will find neither accommodation nor food there. This view is logical and has, moreover, been confirmed by sanitary experts.

I will therefore not discuss the control of rats in the cities but in the open fields, where annually great losses of agricultural products, both European and native, are sustained through the activities of these rodents. It is evident that the situation with us is different. If, in the cities, it is possible to place harvesting and slaughtering products in storehouses where they are practically inaccessible to rats, yet, it must be admitted, that this cannot be said of those products still growing on the fields, so that for the field rat the situation is a different one. No sanitary measures here will check these splendid diggers, swimmers, and climbers, or even annoy them.

Accordingly if the field rat plague is to be eliminated, nothing but the direct control method will suffice.

Even in this case there are many who are sceptical of a successful control. In the above mentioned article two modern remedies were discussed, namely: Ratin and Ratinin. The first is a bacterial preparation and the second a stomach poison. The disadvantages of these two remedies have already been pointed out by those who specialize in these matters, and Dr. Hagedoorn (Archief 1926 1, p. 352) himself expresses very little confidence in them. The final conclusion arrived at in all of this has been summed up by the Experimental Station (Archief 1926 1, p, 394) in these words:

"fundamentally there is nothing to be expected in a country like Java from such methods, in favor of which no satisfactory claims can be presented." Likewise Ratinin has this disadvantage; like every other stomach poison, it arouses the rats' suspicions, who avoid the poisoned bait —and why should they not, considering that they can obtain good food all around them? Further, every stomach poison offers the danger of its reaching stomachs for which it was not intended.

These opinions go even further, since, basically, what they imply is that after all, successful control is quite impossible. This conclusion is based upon the theory that "Under certain circumstances rats will multiply in such manner that their numbers will be in proportion to the available food supply." It is not quite as simple as all that, however; in this case a very speculative hypothesis has been taken as ground for their reasoning. All proof is lacking to show the correctness of it. I do not intend to go deeply into the theory of this matter, but merely wish to take up a few disputed points. In the first place, there are many parts of Java where there is never a scarcity of food, and this cannot there be considered a factor in the breeding of rats, since the number of rodents is not so tremendously high.

Furthermore, a very much exaggerated idea s prevalent regarding the breeding capacity of rats to recuperate lost numbers and maintain the original number. It is overlooked that for every pair of them that is destroyed, arithmetically figured there are as many killed as the living rats should otherwise have produced through succeeding generations. From this it follows that the multiplier diminishes in importance according as the original number is greater and in our case we may consider that such original number was very great.

Now, Dr. Hagedoorn, after many years of investigation, comes to the conclusion p. 307: "A study of damage done by rats in the rice and sugar crops of Java has clearly proven that their extermination is inconceivable, but that a change in the living conditions of these animals will be of assistance, but nothing more." And I would therefore set the question, whether the control itself is not to be considered among such "changed living conditions." According to this authority, No. "The capturing, beating to death, and the poisoning of 99% of the rat population is in reality just as little effective as is the yearly destruction of something less than the natural

increase of rabbits and pheasants by a careful game proprietor." Likewise the Experimental Station declares: (p. 394) "In principle, nothing can be hoped or expected from such control in a country like Java, since the breeding rate in conjunction with the available food supply is such that the destruction of a number of these pests can have but a slight effect and that for but a short time."

If by this we mean only occasional control, as is usually practised, namely at such times as the rats give us most trouble, we must agree with this point of view.

This brings me to the main point which has been left out of consideration: what is actually meant by "control"; where and when is this word in place? To this the answer is: successful control is only possible through continuous and general control.

It is plain—returning to the 99% extermination spoken of by Dr. Hagedoorn—that the original 100% are not obtained if the surviving 1% and their progeny are again destroyed to the number of 99%, before 10% of the original number is attained.

Then there remain but 0.1%. If these and their progeny are again destroyed proportionately before they have multiplied by ten, then there remain but 0.01% of the original number.

By continuous and repated control you do in fact alter the conditions of living and restrict their possibilities of existence. In other words, their number must decrease. If it is owing to mankind that the artificial increase of cats came about, that does not matter; still the natural balance in the natural life of the rat was disturbed and altered.

It must further be borne in mind, that control must not be applied here and there, but over entire stretches of continuous territory.

Dr. Hagedoorn writes (p. 306) "In a single sugar mill, for a period of at least two years, there were killed between nine and eleven thousand rats daily which were gathered subject to reward." And, he states, this lead to no diminution in their numbers.

In this Dr. Hagedoorn took the liberty of making an oratorical gesture, or else the sugar-mill was deceived by the coolies, who for the sake of the reward, brought in rats from far and near. The constant of rat propagation is not so heavy in the year.

Here below we give a table of the kills in rats obtained by a West Cheribon and a Pemalang mill.

RATS KILLED DURING PLANTING YEAR

	WEST CHERIBON		PEMALANG
MONTH	1924-1925	1925-1926	1924-1925
March	7437	3130	——
April	14955	9022	32055
May	22655	38651	283329
June	30723	29270	112843
July	29506	23761	99784
August	20537	11197	321681
September	15076	28884	328069
October	17842	27153	137808
November	21636	20845	Suspended
December	36363	4311	——
January	25952	11191	-
February	16716	9662	-
March	10746	11398	- -
April	14085	327	—— -
Total	284229	128802	1315569

During the months of May and June we note the first great invasion, that is, the time when the young cane seems to attract them. Another great invasion would appear to occur at the time of the large "bandjirs", as can be seen from the figures of West-Cheribon, 1924-1925 —November-January. In that year heavy losses were suffered by that company as well as by others in surrounding territory.

It is interesting to note that in the last year there were few to be seen on that company's grounds in contrast with nearby factories (January-March).

From these figures it follows that we must consider the rat a migratory animal, which settles only where it finds suitable food, now in the cane, now in the rice, etc. Neither control in the canefields nor in the rice fields is in itself sufficient,—a factory must combat these pests throughout the entire extent of its domain and even this will be of little use if neighboring factories fail to do likewise.

One point now comes to my mind in the matter of education on this subject. My standpoint is that occasional control brings no results, since experience has shown that it has had no effects upon these harmful pests. The present practice is to combat the pest only at such times when they cause trouble. This is an unwise practice considering that after going to a expense to control the pest, the door is left open for a greater damage ensuing through a fresh attack, which hangs menac-

ingly like the sword of Damocles over the treated area, likely to strike now or in the following years.

The managers' reasoning is as follows: "as soon as I have trouble with the rats and can present a statement of their damage in figures, my Directors want me to take action against them and my expenditures for the purpose are approved." There is good reason for the Experimental Station to adopt a contrary attitude, but any other method as far as I know, has never been suggested. From this one gathers the impression that the educational service is of the opinion that eradication of the evil is impossible.

It is my intention to have indicated above a means for savings the crops of agricultural products consumed by the field rat each year, namely by a control exercised everywhere without interruption. I shall now take up the objections raised as a rule against this method. These in fact come back to what we have just explained, thus: "If I should continue combatting the rats after they have ceased to cause damage to my plantings and properties, I can show no justification therefor to my Directors, since I cannot prove with figures that I am preventing further damage."

This completes the vicious circle. Because nobody, even if he accepted the truth of this reasoning would dare to exchange "an expenditure for a visible semblance of success" against "an expenditure for a problematical and unseen success." First let the evil occur, then money will be found to combat it. In this way we keep constantly racing behind the facts, but never catch up with or eliminate them.

In fact, the question of borderline control comes up in exactly the same manner. Credit is due Heer Poll (Archief 1925-6) that in several articles he pleads for a control as here described and we do not doubt but that the "problematical and unseen success" will as per "Kalibagor" become apparent after a continuous unceasing control vigorously exercised.

A continuous preventive control affords an advantage which is seldom recognized and practically never taken into account in our modern plant pathology, namely, that the money invested for this purpose must be considered a sort of insurance premium, the benefits of which cannot be forseen.

As a rule, one determines to pay the premium only after a serious catastrophe. Yet one could consider this item as a preventive of a catastrophe like that which overwhelmed us in the 80's.

Now in order to give an instance to illustrate the above point of view, let us mention the following: in Australia, the rabbit which is not a native to the country, was brought in from abroad, and attained such numbers, owing to the absence of natural enemies, as to become a menace to agriculture, and so serious a one that its control has for some years been taken in hand by the Government, and with apparent success since Calcium Cyanide has been used.

This is the remedy which I wish to introduce to the Java Sugar Industry, and which I wish to compare with the controlling materials in use heretofore. These can be divided into three classes:

I. Rat catching with Dogs and Coolies. This method is followed by those companies who constantly exercise rat control. Payment is both by a set wage and by prizes. One advantage of it is that a careful supervision is made of the work done. This method however can never give complete results owing to its inseparable disadvantages.

One. This is a long and expensive process (**) (digging up the burrows).

Two. In opening the burrows, the older rats mostly manage their escape, whereas the younger ones, too immature for reproduction are the ones destroyed.

Three. As the numbers diminish, their control becomes more difficult. Now the coolies who have been working for a prize lose interest in locating and destroying the holes and nests, and may even bring rats from the outside.

II. Stomach poisoning: (comprising bacterial and serum preparations). This affects mainly the full grown rats. Its disadvantages are:

One. Very soon the animals become suspicious of the bait and avoid it. The bait must constantly be varied in point of looks and make-up which becomes excessively costly.

Two. Only rats who by chance come near the bait are affected.

Three. Danger to other animals, such as young cattle, goats, and the like.

**According to accurately calculated figures, the cost per rat caught varies from 0.92 to 12.01 cents. The greater the number of rats, the smaller is the cost of each rat destroyed.

III. Respiratory poisoning: The advantage herein afforded is that all animals, large and small, can be reached in their burrows as well as in their day-time refuge. Up to now all respiratory poisons offered serious disadvantages. Many such remedies (for instance, carbon disulphide) are either too expensive or too slow. Others work very rapidly but are dangerous to the men handling them. Among these stands hydrocyanic acid gas, which works immediately, and is used for rat extermination aboard ship. The handling of the generators, which are hard to transport, also proved very dangerous to the native laborers. Among these remedies too, must be included Calcium Cyanide.

This is a product of the "American Cyanamid Company" of New York, who utilize the Niagara Falls for the conversion of atmospheric nitrogen into Calcium Cyanide. It is supplied in various forms, all of which contain a definite percentage of $Ca(CN)_2$.

The greatest advantage of this remedy is that while hydrocyanic acid gas (HCN) is still used as the poison, the "generator" of the gas, i.e. the material from which the gas is formed, is itself in a harmless condition at the time it is inserted in the burrow.

Through the action of the atmospheric humidity which is always present in the burrows in sufficient quantity, the following reaction is obtained.

$Ca(CN)_2$ plus $2H_2O$ gives 2 HCN plus $Ca(OH)_2$

Another exceptional adantage is seen from the following comparison: that the formation of the gas leaves behind only a completely harmless product: viz.,—slaked lime.

Below we give the results of a few experiments. We took two types, namely: the "granular", having large grains, which we inserted into the burrow by means of a long-handled spoon; the "A" Dust, a very fine powder that is blown into the burrow by means of a "Duster."

The granular material was used, among other places, at the "Soerawinangoen". On March 29th tests were made in my presence. Our first purpose was to determine the proper dose and the rapidity of the effects. A number of rats were brought together in a pit two feet deep, comprising 1 full-grown, five half-grown, and ten very young ones. In this pit about 1 gram of the cyanide was placed.

The full-grown rat died within one minute, the half-grown were unconscious and in convulsions, the young ones

were frolicking gayly. After five minutes' time the half-grown ones had also perished, and the young fellows just unconscious. Then 1 more gram was added and within ten minutes' time the whole lot were dead.

The older the rats, as was found likewise by further experiment, the sooner they perished. Moreover it was found that the unconscious animals even if immediately carried into the fresh air did not recover. They die without recovering consciousness, and in the throes of severe convulsions particularly of the respiratory organs, without a chance to survive.

In further experiments three grams of cyanide were placed in a burrow by means of a small Z.A-spoon, the opening was then slightly covered with earth, and after a few minutes the burrow was dug out. The kill in all cases proved to be complete. Only once did a full-grown rat succeed in escaping through another outlet but only to fall to the ground where after going through the above described convulsions, it finally died. Sometimes it turned out that the burrow was infested by a snake instead of the rats. These were found dead also.

The other material, the "A" Dust, was used in experiments at "Kadipaten", using a duster like the one used in Australia for the control of rabbits. This apparatus, a "duster" so-called, was sent to me by the firm of Buzacott & Co. Ltd. of Sydney, and works very well, measuring automatically the required quantity for each burrow. This apparatus is not however quite adapted to our needs. It is too large to be carried through our canefields or to be borne by a single coolie. Moreover its construction does not seem to be strong enough to withstand the treatment it receives at the hands of our coolies. The plan of another apparatus is being drawn up by us at the present time.

Further it appeared to me at the time of my visit on April 28th that the effect was much faster and again the kill was complete. The application is however somewhat more difficult.

At both plantations the holes were traced by dogs which had been used by these companies for rat hunting. At the opening of one of the burrows that had been treated with the "Granular", a dog came near, sniffing at the burrow, and was brought to only with the greatest difficulty. In the "A"-Dust" experiments, a dog that was just as careless dropped dead immediately.

We mention this in order to point out the great danger involved in opening the hole or burrow too soon. The coolies particularly are prone to this error, because they cannot realize how so small a quantity of the powder can have so deadly an effect. They wish to convince themselves immediately of the miracle wrought and are even more careless about it than the dogs.

I will sum up the advantages as follows:

I. The exceptional simplicity of application, particularly of the "Granular" form.

II. The very rapid and unfailing effectiveness.

III. The small cost because of small dosages: nearly no transportation expenses, no loss of time provided the opening of the burrows is forbidden.

IV. The dosing powder is harmless when being used, except when in contact with open wounds when it is very poisonous.

V. The dangerous hydrocyanic acid gas is generated underground.

VI. The only residue is harmless slaked-lime.

When its application is properly organized, there are no disadvantages connected with this method. The possible dangers may be easily avoided as they exist or occur through carelessness.

It must be observed that during the damp season the containers holding the cyanide must be tightly shut,—whether stationary or in transport. When using the "Granular" it is necessary to work quickly. The containers must be kept open as little as possible. When it rains, its use should be altogether forbidden.

Another danger, at stated, lurks in too early an opening of the burrows. In my opinion, no good comes of this and it should absolutely be forbidden. I have already suggested this, but the answer was made me that the coolie cannot be restrained or controlled. This is quite true but the degree of exactness with which this control is carried out does not compensate, to my mind, for the enormous loss of time consumed by opening the burrows.

A coolie, who has nothing more to do than to poison the holes, which he has located with the assistance of a dog, accomplishes much more than a group of three or four coolies who must dig up every burrow (after at least 10 minutes watching) and then close it again.

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A coolie, who has nothing more to do than to poison the holes, which he has located with the assistance of a dog, accomplishes much more than a group of three or four coolies who must dig up every burrow (after at least 10 minutes watching) and then close it again.

The latter method does not only cost many times the first but it has the further disadvantage that every day there is a smaller area treated, with the result that after much longer periods you have to return to the same grounds.

In my opinion, rat control should be so organized that the company distributes over the whole area a sufficient number of "Cyanogas" coolies so that each coolie will at least once every two months return, within his territory, to any given spot. These men have nothing else to do than to hunt up the burrows within their territory with the assistance of a dog, to insert the cyanide in each of these burrows and then to close them at the top. They must not limit their search to the canefields alone, but must look everywhere, including rice fields, etc.

It goes without saying that when employing many coolies the cost of each rat destroyed is almost nothing because there are such tremendous numbers killed. It is therefore self-evident that as the number of survivors decreases, the cost per rat kill increases, considerably. The greater the cost becomes, that is, the fewer rats killed, the more effective is the control obtained.

Everybody agrees that this is theoretically correct but that in practice a reasonable ratio must be maintained between the control expenses and the cost per rat destroyed. If practically no more rats are being caught, the work is not abandoned, but the "Cyanogas" staff is proportionately reduced in order to attain the suggested ratio.

It is clear that also for this purpose a certain supervision must be kept. The coolies should therefore be subject to checking up at irregular intervals, while every now and then the burrows may be opened, in order to get an idea of the number of rats still living.

Above all things it must be remembered never to completely suspend control operations, even when practically no more rats are noticeable, nor should this control be restricted to the cane fields alone. A control of the kind here described would therefore be of great advantage to the native inhabitants. In these countries the population also view this very favorably, and I consider it very likely that they would be willing to use any material that the factories would offer them for the purpose. I therefore judge, without entering into details, that it would in many cases be possible to come to an understanding with the population, so that the control

of this common enemy will not entail too heavy an expense for the factory.

Further it should be mentioned that this cyanide destroys all animal life, yet does not injure the plant in the least. Therefore this remedy may be successfully used for "white grub" and termite plagues. In countries using "white labor" they go still further, using it for harmful animal pests above-ground like aphids, caterpillars, etc. but it appears to the writer to be advisable then to use gas masks with a basic nickel-carbonate of sodium-sulphate.

As regards the "white-grub" plague, we shall gladly supply further information. The "Cyanogas" products of the American Cyanamid Company are not yet obtainable in Java. However on successful completion of our experiments, the International Credieten Handelsvereeninging "Rotterdam" was appointed by the manufacturers as their Java Agent.

District of Cheribon, June 1926.

Issued October 25, 1926.

Experiments in the Control of Scavenger Termites in India and Ceylon By Means of Calcium Cyanide

By

W. H. Brittain, Ph.D.

As a group termites are among the most ubiquitous and destructive of all tropical pests. Their keen appetite for cellulose makes them especially dreaded by the builder and the number of products placed on the market for the purpose of rendering timber "termite proof", testifies to the extent and importance of their ravages. Certain species attack the living tissues of herbaceous plants, while others burrow in the living wood of trees and shrubs. Examples of the latter are *Calotermes militaris* and *Calotermes dilatatus*, well-known and destructive pests of tea in Ceylon. In addition to the foregoing there are various species of scavenger termites that are indirectly a cause of considerable trouble and annoyance. The presence of their unsightly mounds in private or public grounds and gardens is greatly abhorred and interferes with the cultivation of useful or ornamental plants. Their mounds and tunnels upon golf greens, race courses, cricket fields, meadows, etc., interferes with the activities carried out in such situations and, in some cases, their undermining tunnels render the grounds quite unsafe for riding purposes, especially during the rains. We have also known the activities of these insects to render impossible the use of horse machinery on badly infested fields. In mud-floored warehouses or godowns erected for the temporary storage of such a product as jute, they frequently cause great havoc.

The destruction of the termite colony, which is necessary to affect permanent suppression, is attended with a number of difficulties. The large numbers of distinct fungus gardens present in the larger colonies, the large number and small size of the communicating tunnels, the habit the insects have of stopping up their tunnels when the colonies are disturbed, etc., combine to render the successful treatment of the termite nest a problem of some complexity. Native gardeners and coolies have their own ways of dealing with such problems and do not take kindly to methods involving the use of machinery, however simple. Digging out the nests and destroying the queens is the method commonly resorted to on golf links, public grounds, and estates. Sometimes a premium is paid for each queen destroyed and little, if any, attention is paid to the brood.

This laborious and expensive method may appear to be successful for a time, especially if done during the dry weather, but as the soil is very hard and dry at that time, this is rarely possible. It usually happens that a large proportion of colonies so treated soon spring up again as the production of "substitute queens" within the colony enables the insects to establish it anew. During the rains we have repeatedly observed that such colonies spring up again in the newly turned earth, within a week or two of the destruction of the queens, though it may take some time for a mound that has been the work of years to attain its original dimensions.

Various materials have been recommended for the destruction of these pests under the conditions described and machines have been devised for the express purpose of pumping various gases into the nests of the termites. None of these have been more than partially successful and most of them have proved to be too cumbersome or complicated for use by the ordinary coolie. The result has been that after a few trials they have been discarded and the old method of digging out the queens resorted to. The success of the "Cyanogas" method in dealing with other burrowing animals and the simplicity of the method of application, suggested the possibility of its use in connection with the control of mound-building termites and the following is an account of a number of preliminary experiments undertaken in India and Ceylon.

Experiments at Dacca, Bengal

A few preliminary experiments were undertaken at Dacca, Bengal through the courtesy of Mr. R. S. Finlow, Director of Agriculture and Mr. P. C. Sen, Entomological Assistant. The colonies treated were situated partly on the golf greens or tennis courts and partly in and about a jute godown or warehouse, where the activities of the insect not only interfered with operations, but also resulted in loss of the baled jute from the insects feeding upon it.

The method followed was to insert the delivery tube of the pump into a number of the main tunnels in succession, pumping until it appeared that the area was sufficiently "gassed." Soon after pumping started the dust would be seen issuing from a number of openings which were then closed with wet earth. After completing one opening another was opened at another place and the process repeated until the colony had been treated from all sides. The results, which are set forth in the accompanying table (No. I) indicate that under the existing conditions and amounts used the treatments were, on the whole, quite successful.

TABLE No. I

Experiments in the Destruction of White Ants (*Termes obesus ?*) with Cyanogas Calcium Cyanide "A" Dust Applied with A Small Cyanogas Pump.

Locality:—Decca, Bengal
Date: —March, 1926.

Dose in Oz.	No. of Openings Treated	Approx. % of brood Killed	Queen	Remarks
3	1			Small mound not opened; no sign of life; under observation.
8	3			Not opened: no life: mound covering 3 x 5 ft.
13	4			Not opened: no sign of life, mound 5 x 3 feet.
14	3			Not opened: no sign of life, mound 4 x 3 ft.
14	6	100%	dead	5 x 7 ft. mound, 4 substitute queens also killed.
14	7	98%	dead	Similar to above.
15	5	89%	alive	6 x 3 ft: situated in hedge and hard to treat.
15	5			Not opened: no sign of life, mound 6 x 5 ft.
16	6	100%	dead	Mound covering 7 x 5 ft.
16	8	98%	dead	Out door mound, covering 4 x 6 ft. of ground space.
20	4	99%	Not found	In godown covering 5 x 4 ft.
20	6	100%	dead	Mound covering 5 x 4 ft.
28	5	50%	Not found	Mound 7 x 3 ft. Badly done by coolies not under supervision of experimnter.
32	6	99%	Not found	In godown covering 8 x 3 ft.
32	6	99%	dead	In godown covering 12 x 4 ft. of space. Queen at 4½ ft.
40	6	96%	dead	In godown covering 7 x 4 ft.
40	6	100%	dead	Mound in godown covering 9 x 5 ft. Queen at 4 ft.
45	7	98%	dead	In godown covering 15 x 8 ft.
48	7	99%	alive	Mound in godown covering 16 x 8 ft. Queen chamber was under a piece of stone flooring at 2½ ft. and well protected in a cavity of the stone: in all other places brood killed.
48	7	99%	dead	In godown covering 16 x 9 ft.
45	6			In godown, large irregular mound, partly covered by jute and hard to reach, not opened. No sign of life 2 months after treatment.

Experiments at Poona, Bombay Pres.

Tests were carried out at Poona under the direction of Prof. T. N. Jhaveri, L. Ag., using material and apparatus supplied by the writer. The tests were made during the dry weather, and, as only a partial control was secured, the results were by no means satisfactory. Later, other tests were made under the personal direction of the writer, the work being performed at the commencement of the rains. The results, which were checked and forwarded to the writer by one of Prof. Jhaveri's staff were again unsatisfactory, several of the queens and a large percentage of the brood of the treated colonies having escaped destruction. In view of the much more satisfactory results obtained elsewhere, it is evident that the relation of soil moisture and other factors affecting results should be made the subject of special study.

Fig. 1.—Applying Cyanogas for the Control of Termites Infesting a Jute Godown. Dacca, Bengal, India.

Experiments at Peradeniya, Ceylon

The experiments in Ceylon were carried out after the rains had already started and the soil was in all cases well saturated with moisture. Frequent rains occurred during the course of the operations and the insects were active on the surface at all times. The first series were performed on the golf links and only comparatively large colonies were treated, and those of as nearly an equal size as could be secured.

Three different points were considered in this series:

1. The foot pump vs. the spoon method.
2. Introduction of the material through a single opening as compared with its introduction through two or more openings.

Difficulty was experienced in connection with the use of the foot pumps, which, not originally adapted for use in the hot, humid climate of Ceylon, soon began to give trouble and finally went out of commission altogether. The results in this series, therefore do not represent the results that might be expected from the new style foot pumps, which give a normal pressure.

SERIES I

The results obtained are set forth in the accompanying table (No. 11). In order to gain a rough idea of the size and extent of the different mounds their greatest length and width is given in each case.

TABLE No. 11

Experiments in the Destruction of Termites with Calcium Cyanide in Ceylon.

Locality: Peradeniya, Ceylon.
Date: May, 1926.

Cyanogas Foot-Pump used except where stated otherwise.

Species of Termites: *Odontotermes obscuriceps*, Wasm. and *Odontotermes redemanni*, Wasm.

Species	Dosage in Oz.	No. of holes through which Applied	% of Brood Killed	Queen	Remarks
(*O. redemanni*)	3	3	75	alive	Nest 12 x 10 ft.
	4	1	75	dead	Nest 6 x 6 ft.
	8	1	99	dead	Nest 9 x 7 ft.
	8	1	99	dead	Nest 8 x 6 ft.
	8	2	100	dead	Nest 7 x 8 ft.
(*O. obscuriceps*)	4	1	65	dead	Nest 5 x 6 ft.
	4	1	90	dead	Nest 8 x 5 ft.
	4	1	95	alive	Nest covering space of 8 x 12 ft. Queen protected by boulder.
	4	1	100	dead	Nest 9 x 8 ft.
	4	2	50	alive	Nest 8 x 8 ft.
	4	2	99	dead	Nest 9 x 8 ft.
	4	4	40	alive	Applied with a spoon. Nest 8 x 6 ft.
	4	4	99	alive	Nest 8 x 5 ft. Queen protected by large flat stone.
	8	1	65	alive	Nest 18 x 6 ft.
	8	1	95	alive	Nest 12 x 8 ft. 3 large boulders blocked way to queen chamber.
	8	1	100	dead	Nest 8 x 5 ft.
	8	4	50	alive	Nest 13 x 8 ft. Spoon used.
	8	4	50	alive	Nest 10 x 12 ft. Applied with spoon.
	16	4	99	dead	Nest 13 x 8 ft. with large chimneys 3 ft. high.

Discussion of Results

It is difficult to make useful comparisons between the results secured from colonies differing in size, form, character of nest, and nature of the ground. Nevertheless, certain facts appear clear. The use of the foot pump evidently increases the efficiency of the treatment, as does the introduction of the dust into the greater number of burrows, other factors being equal. It would also appear that in the treatment of such large nests, less than one half pound of material is usually inadequate.

SERIES II

In this series is a continuation of Series I, in this case the application by means of a spoon being entirely abandoned, and a "Cyclone" duster, used in crop dusting, being used in the absence of a foot pump. The amount of material used was such as our former experiences indicated would be adequate. The results are indicated in the following table (No. III).

TABLE No. III

Experiments in the Destruction of Termites with Calcium Cyanide

Locality: Peradeniya, Ceylon. Experimenter: W. H. Brittain.
Date: May, 1926. Method: Cyclone Duster.

Species of Termite: *Odontotermes redemanni*, Wasm.

Number	Dosage in Oz.	No. of holes through which pumped	% of Brood Killed	Queen	Remarks
6	8	3	95	alive	Royal chamber under large stone. Nest 8 x 12 ft.
12	8	4	100	dead	6 x 8 ft.
13	8	4	100	dead	5 x 5 ft.
10	16	2	100	dead	7 x 12 ft.
7	16	4	95	dead	8 x 9 ft.
8	16	4	99	dead	8 x 5 ft.
9	16	4	100	dead	10 x 7 ft.
11	16	4	100	dead	8 x 11 ft.

Discussion of Results

The results here are such as to indicate that the method and amounts used in treating nests of this size is satisfactory. It is never never possible to destroy all colonies entirely, as certain physical features sometimes prevent complete penetration but the average control secured here is good.

SERIES III

Experiments in Control of *Odontotermes redemanni* With Calcium Cyanide

These experiments were carried out in the Royal Botanic Gardens, Peradeniya, in co-operation with the curator.

The conditions here were peculiar and by no means typical. The grass being cut at regular intervals the mounds are being constantly rolled out flat, so that the insects are driven to continue their activity below the ground. A small bare spot on the surface often denoted an extensive system below ground.

The method adopted in treating this area was the same as in other cases, the dust being pumped into a number of burrows in all but the smallest nests and openings stopped with damp earth. Owing to the conditions described, it was difficult to detect all the main connections and it is more than likely that some were missed.

The green being almost entirely undermined by the insects it would have ruined the turf to dig out all the nests and so another method of checking the results had to be adopted.

Twice the treated area was gone over and any renewed activity noted, the second occasion being just before the next mowing of the grass necessitating the removal of the stakes to mark the treated colonies.

Not only were the mounds, or rather the sites of the former mounds examined externally, but each of them was dug into with the digging tool in an effort to detect any signs of renewed activity.

The results of our examinations are indicated in the accompanying table (No. IV), the absence of activity on the part of the insects being indicated by an X in the appropriate column, doubtful cases being indicated by an interrogation mark.

Discussion of Results

There was only a single definite case of renewal and that was one small spot in the large nest around the Bo-Tree which was quickly retreated with a few strokes of the pump. There were two other cases where small mounds had appeared midway between two treated colonies. They may have been from one or the other of the treated mounds or they may have been new colonies. It would be difficult to say. They also were treated by a few strokes of the pump and neither showed signs of further activity.

TABLE No. IV

Experiment in the Control of *Odontotermes redemanni*, Washm. with Calcium Cyanide

Locality: Royal Botanic Gardens, Paradeniya, Ceylon.
Date: May 1-10, 1926. Duster: Cyanogas Foot Pump (Small)
Date Checked: June 10-12.

No. of Expt.	Dose in oz.	No. Holes through which pumped	Signs of Renewed Activity Yes	No	Location	Size of pest in feet
40	1	1	?	?	Great Circle	1 x 2
41-46, 104	1	1		x	" "	1 x 2
48-53, 76, 92, 93						
96-102	1	1		x	" "	2 x 2
79	1	1		x	" "	2 x 3
78	1	2		x	" "	2 x 3
47, 62-67	1½	1		x	" "	2 x 2
57, 58, 59	2	1		x	" "	2 x 2
25a, 69-74	2	1		x	" "	2 x 3
81, 82, 84, 85	2	2		x	" "	2 x 3
95	2	2		x	" "	4 x 2
86-90	2½	2		x	" "	3 x 4
25	3	2		x	" "	5 x 6
35	3	3		x	" "	5 x 3
5	3	3		x	" "	6 x 3
10	4	2		x	" "	2 x 2
28, 29	4	2		x	" "	4 x 5
27	4	3		x	" "	2 x 3
11-13	4	3		x	" "	3 x 5
23	4	3		x	" "	4 x 5
17	4	4		x	" "	3 x 5
106	4	4		x	" "	6 x 4
34	5	2		x	" "	4 x 6
8	5	2		x	" "	6 x 7
14	5	3		x	" "	3 x 6
6, 22	5	3		x	" "	5 x 5
30, 31	5	3		x	" "	6 x 5
20	5	4		x	" "	3 x 6
16	5	4		x	" "	4 x 6
68	5	4		x	" "	5 x 6
32	5	5		x	" "	6 x 6
56	6	3		x	" "	7 x 3
24	6	4		x	" "	6 x 5
33	6	4		x	" "	7 x 6
103	6	4		x	" "	7 x 8
18	6	5		x	" "	6 x 4
15	6	5		x	" "	6 x 5
7	7	4		x	" "	6 x 6
19	7	5		x	" "	6 x 8
26	8	3		x	" "	6 x 5
91	8	3		x	" "	6 x 8
39	8	4	?	?	" "	6 x 4
77	8	4		x	" "	6 x 5
75	8	4		x	" "	7 x 4
38, 55	8	4		x	" "	7 x 5
36	8	4		x	" "	7 x 6
80	8	5		x	" "	7 x 5
83	8	5		x	" "	6 x 9
37	8	5		x	" "	8 x 5
105	8	5		x	" "	9 x 5
54	9	4		x	" "	7 x 6
94	9	4		x	" "	6 x 9
61	10	4		x	" "	8 x 7
9	10	4		x	" "	9 x 12
60	10	5		x	" "	8 x 6
1	16	4		x	Great Lawn	10 x 8
2	16	4		x	" "	12 x 9
3	20	6		x	By orchid house around wax palm	Very large
4	20	6	x	–	King Edward	. . .

Conclusion

The foregoing experiments indicate that calcium cyanide possesses promise as an insecticide for the species discussed and under the condition decribed. Further research may clear up the reasons for the cases of failure reported and wider experience would doubtless result in a more efficient application of the material. Present experience indicates that this method can be expected to produce satisfactory results when material and foot pump are kept constantly on hand and used whenever new colonies became evident, and that it will give more reliable and permanent results at a lower cost than the older method of digging out the nest and destroying the queens.

Fig. 2.—Termite Mound Excavated After Treating With Cyanogas.

In attempting to apply this remedy to the control of termites it is advisable to proceed only when the ground is saturated with moisture and the termites are active at the surface. The exact dosage to be given and the number of points at which the material should be introduced depend upon the size, form, and general character of the nest and it determination will be largely a matter of experience.

The general form of the colonies to be treated may vary considerably. In some cases there is a single, high, more or less upright mound, though it should be noted that there may be fungous gardens well outside the area indicated by the

surface mound, but, nevertheless, the colony is fairly compact. In other cases the colony is very diffuse, large numbers of smaller mounds, indicating the presence of fungous gardens beneath, being spread over a considerable area. In the first case it will not be necessary to introduce the dust at so many points as in the second, though care should be taken to see that those fungous gardens outside the apparent area, as indicated by the surface mound, are thoroughly 'gassed.' It is inattention to this important detail that results in partial failure. In the case of those mounds of the more diffuse type the larger the number of fungous gardens into which the dust is directly placed, the better are the chances of completely exterminating the colony. The best practice is to pump a little dust into several of the holes, reserving the main pumping for that point which appears to result in the maximum amount of gassing of the entire colony.

The Importance of Nest Structure in the Control of Certain South African Termites With Cyanogas Calcium Cyanide

By

R. Owen Wahl and Adinor R. Powell

Introduction

The adaptation of the Cyanogas Calcium Cyanide method for the control of termites has been taking place in various parts of the world simultaneously. In Australia, Jarvis *(1) reports that experiments with calcium cyanide for the control of termites, *Eutermes veroni*, Hill, and *Termes sp.*, were very successful. He also reports that from 2 to 3 ounces of calcium cyanide flakes in a hole made at the top of the termitarium and afterwards sealed with wet soil is an effective remedy against *Coptotermes acinaciformis*, Frogg. which is a pest of sugar cane (2). In Ceylon, Brittain (3) reports the successful control of *Odontotermes redemanni*, Washm. and *O. obscuriceps*, Washm. and a failure to control the tea termites of the species *Calotermes militaris*, Desn. and *C. dilatatus*, Buignon and Popoff. Jepson (4), also of Ceylon, reports that *Calotermes militaris*, *C. dilatatus*, and *C. greeni* were not controlled due to the fact that is was impractical to apply the calcium cyanide to the burrows in the tea bushes. Patterson (5), working in the Gold Coast, was able to secure but a 50% kill of *Macrotermes bellicosus*. In India, Brittain (6) found that the common termite found in jute godowns and those infesting golf greens could be controlled with Cyanogas Calcium Cyanide A-Dust when applied by means of a duster. Bromley (page 3-4) reported that species of *Cryptotermes* infesting furniture in a library in Cuba were killed in the furniture during an ordinary house fumigation. Snyder (7) reports that for the protection of growing plants calcium cyanide mixed with the soil at the rate of two ounces per square yard may be used but that it should not be placed near the plants. This work was carried out against species of subterranean termites infesting the soil in the southern parts of the United States.

From these published references it can be seen that the use of Cyanogas Calcium Cyanide has been tried under varying conditions and with variable results. It would appear that this material is adapted to the control of those species which belong to the groups generally referred to as the mound-building termites and that in the case of other types of termites, although the gas is equally toxic, a practical application cannot be made.

* Numbers refer to literature cited.

In order to wipe out a colony it has been considered necessary to kill the queen and the entire brood otherwise the insects are able to survive and by the replacement of the queen are able in a short time to regain their lost numbers. In actual practice, however, it has been found that if the queen and a better than 80% kill of the brood be secured that the colony will usually die out. To kill the brood it is necessary that the killing agent used penetrate to the uttermost portions of the nest and this fact makes the method of application a prime factor in determining the success of the treatment.

In South Africa there is a wide range of termite species and in the preliminary experiments with Cyanogas Calcium Cyanide for the control of termites variable results were obtained. The senior author undertook a careful study to determine what species could be successfully controlled, those which were difficult to control, and to determine if possible the reason for the failure to control certain species. This work has been greatly facilitated by the assistance rendered by Claude Fuller, the present Chief Entomologist of the Department of Agriculture of the Union of South Africa, who for many years has made a special study of termites. He has aided by the determination of the species studied and has given many helpful suggestions in the best methods to be adopted in treating the nests. Most of the sketches shown in this paper are drawings made from published and unpublished work of Mr. Fuller. Mr. O. J. Els has assisted in the development of the use of the soil auger which method he suggested.

In treating various species and later digging out the nest it was apparent that the material was effective when it reached all parts of the nest but that in some species in spite of careful application of high dosages it was found that a complete distribution of the dust had not been secured. Excavations of such nests indicated that applications had been made to galleries which led away from the nest, into air pockets, or into blocked chambers. These observation led to the study of the construction of the nest by various species and an adaptation of the treatment based upon the structure of the nest. This paper will deal primarily with the proper application of the Cyanogas to nests of various types of temites since it is felt that some of the species in other countries which have been treated unsuccessfully could be treated with success should the application of the material be governed by the structure of the nest.

Eutermes trinervius

In general the mounds of this species represent a simple type of nest which is very easy to treat successfully. Two or three ounces of Cyanogas Calcium Cyanide A Dust should be pumped into several of the large galleries on opposite sides of the nest. The holes are then closed. In some cases excellent results have been secured by breaking into the mound and applying the dust directly to the brood chambers and then closing the openings. The experiments with this species are included in Table I.

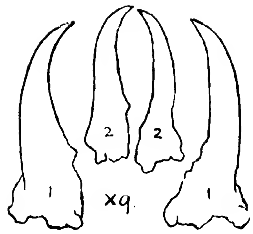
TABLE I

Experiments with *Eutermes trinervius*

Pump Used	Dose in Ozs.	No. of Treated Openings	% of Brood Killed	Queen	Remarks
Feeny Duster	2	1	80%	Killed	Crust not broken. Ants alive at end furthest from opening.
Feeny Duster	6	2	90%	Killed	
Incledon	6	2	90%	Killed	In the heart of the *trinervius* mound was a small *badius* nest but they must have sealed up the *trinervius* runways leading to their domain, as no dust penetrated to it.
Feeny Duster	2	1	100%	Killed	Crust of mound broken in various places for draught.
Incledon	8	2	100%	Killed	
Incledon	7	3	100%	Killed	
Incledon	8	2	100%	Killed	
Incledon	6	3	100%	Killed	

Macrotermes natalensis

The Natal termite, *Macrotermes (Termes) natalensis,* Hav. is generally distributed over Rhodesia, Natal, Transvaal, and the Orange Free State. It is also found as far south as Kimberly and in the Kalihari. The soldier caste has both major and minor types, the latter occurring in greater numbers. They have broad, flat heads which taper toward the forehead and are equipped for biting with strong, toothless, sabre-shaped jaws or manibles. (Fig. 1). The food of this species is largely confined to grass and wood. They cause enormous losses by damaging the flooring in houses and when outside are particularly destructive to fence posts. The typical nest is usually conical above ground and filled with irregular vertical galleries which extend down into the main nest. The fungus gardens, brood chambers, and queen cell are usually found directly beneath the mound but below the surface of the soil. Just below the soil surface are many horizontal galleries through which food is taken directly into the nest. Fig. 2-A).



Mandibles of Macrotermes natalensis

1. Major. 2. Minor.

Fig. 1.

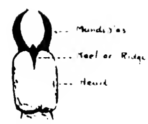


Fig. 3.—Head of *Macrotermes bellicosus*

It will be noted from figure 2 that an attempt to blow dust into the main nest through the mass of irregular galleries which ramify through the external mound would be very difficult if not impossible. The experiments given in Table 2, show the difficulty in treating through the mound. On the other hand it will be noted that the horizontal galleries (Fig. 2-A) offer a direct path to the main nest. For this type of nest the most effective method is to dig a trench on either side of the nest in order to locate and open up the horizontal galleries. Two or three ounces of Cyanogas per opening should be blown into the galleries from opposite sides of the nest. The holes should then be closed with moist earth. In addition the mound can be broken into and two ounces of the dust be blown into several of the larger vertical galleries. When treating such a nest it is well to create a thorough draught and to close the holes from which the dust is seen to escape.

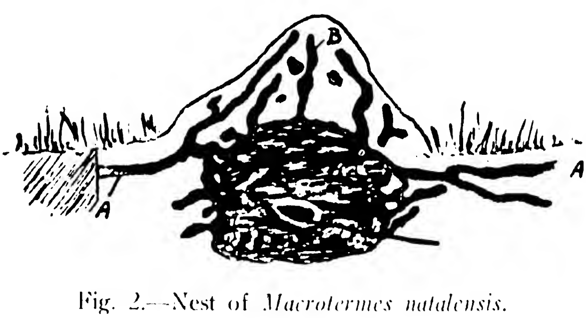


Fig. 2.—Nest of *Macrotermes natalensis*.

TABLE II

Experiments with *Macrotermes natalensis.*

Pump Used	Dose in Ozs.	No. of Treated Openings	% of Brood Killed	Queen	Remarks
Incledon	6	1	20%	Alive	Dust penetrated brood chamber from top. Due to its enormous size (nearly 3 ft. in diam.) only small percentage of brood killed. Queen found 2 feet from surface.
American Beauty	5	3	25%	Alive	Very large nest with many old brood chambers which probably prevented dust from penetrating to main nest which was about 4 feet from surface.
American Beauty	4	4	40%	Alive	Nest fairly large—undoubtedly too little dust used.
Feeny	6	3	60%	Killed	Very large nest. Dust failed to penetrate beyond queen's present brood chamber.
American Beauty	4	1	75%	Not found	3 brood chambers found—dust failed to penetrate one. Two field mice found dead.
Incledon	9	2	80%	Killed	Nest 2½ ft. from surface. Dust penetrated brood chamber from two sides. Termites not killed found mainly at top of brood chamber—rest at bottom. Had pumping been carried on longer, dust would have spread to these parts making kill complete.
American Beauty	4	3	95%	Dead	Dust failed to penetrate an old brood chamber some distance from where queen was found.
American Beauty	3	1	100%	Not found	Queen most probably killed.
American Beauty	3	1	100%	Killed	Small nest with only a few main tunnels.

Macrotermes bellicosus

Macrotermes bellicosus, Smeath. is confined to the valley of the Limpopo, the northern part of the Kalihari and practically all of Portuguese East Africa as far north as the Maputa river. This species resembles very closely *Macrotermes natalensis.* There are two kinds of soldiers present, the major and the minor but in this species the minor soldiers are smaller than those of *natalensis.* They can be easily distinguished from each other by the sculpturing on the frons or forehead (Fig. 3). In *bellicosus* there is a long narrow keel or ridge on the middle of the frons which extends from the frontanella pore to the front of the head. This ridge is absent in *natalensis.* The sides of the head are parallel in *bellicosus* but taper toward the forehead in *natalensis.*

In both food habits and nest structure (Fig. 4) the members of these species are so similar that the same method of treatment can be recommended for each.

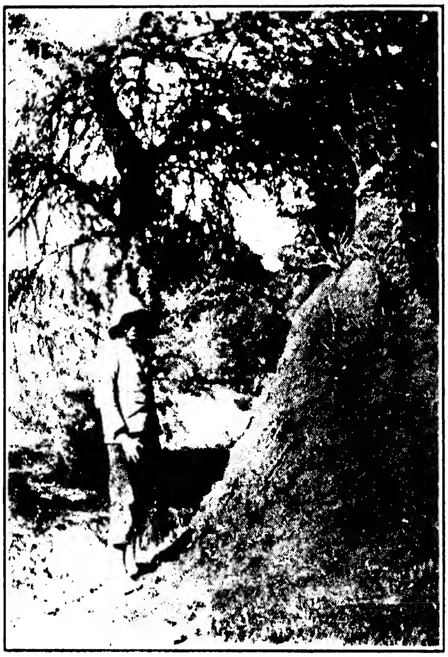


Fig. 4.—Nest of *Macrotermes bellicosus* Taken in the Transvaal.

Odontotermes badius

The Insidious termite, *Odontotermes badius*, Hav. is widely distributed in the Transvaal and Natal. It also occurs in Zululand, the Orange Free State, and at Kentani and Colesburg in the Cape Province. The soldiers intergrade in size from the largest to the smallest, there being no distinct types as in *Macrotermes bellicosus* and *natalensis*. They have large, strong mandbles which are toothed once, the tooth on the right mandible being smaller than the one on the left. The upper margin of the mandibular tooth slopes down from the jaw making an obtuse angle with it (Fig. 5). These soldiers do not bite when disturbed but eject a brown fluid which serves as a repellant.

This species is very destructive as it is a voracious feeder on all sorts of wood work and also attacks living trees, eating the bark from the roots and stems. It works under a clay canopy even in the dark and unlike the other species it does not tunnel but removes the wood in layers. The typical nest is usually in a shady place and consists externally of numerous close-set moundlets which are not hard (Fig. 6). Beneath each moundlet is a gallery which runs into the main part of the nest. When a *badius* nest is in a clump of trees the mound may closely resemble that of *Macrotermes natalensis* and can be treated in the same manner recommended for that species.

(Fig. 7). These, however, are much more difficult to treat and great care should be taken in making the application.

A nest of such simple construction provides an easy access to the brood chambers and queen cell. Three or four of the largest galleries under the moundlet should be selected and two ounces of Cyanogas A Dust blown down each. A better distribution of the dust is obtained if the galleries selected be on opposite sides of the nest. The treated openings and any others that are visible should be closed immediately.

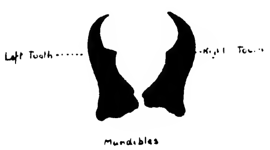


Fig. 5.—*Odontotermes badius.*

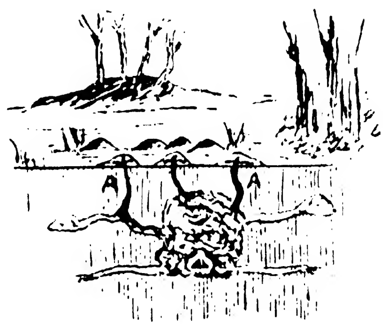


Fig. 6.—Typical Nest of *Odontotermes badius*

The most effective treatment of this type of nest can be made by boring into the main nest by means of a soil auger similar to a tree planter but smaller. The auger used in South Africa is about 2½ inches in diameter, with blades six inches in length. The position of the main underground nest can be easily determined by the position of the mounds. In the case of only one mound the hole is drilled on any side about 18 inches to 2 feet away. Where there are two mounds the hole should be drilled 18 inches from the largest mound, on the side toward the smaller mound. In the case of three mounds in the form of a triangle the boring should be made 18 inches from the largest mound on the side toward the smaller mounds in the center of the angle formed by the three mounds. Where there are several mounds situated parallel with each other the boring should be made about two feet from the largest mounds in the direction of the other mounds. In this case at least two large mounds should be selected. All openings so treated should be closed after treatment.

TABLE III

Experiments with *Odontotermes badius*

Pump Used	Dose in Ozs.	No. of Treated Openings	% of Swarm Killed	Queen	Remarks
Incledon	8	3	About 50	?	Largest nest built around small thorn bushes. Impossible to open up whole nest owing to bushes.
Feeny with dust container attached	8	3	70	Killed	Nest with large surface area and containing four fungus gardens. Dust penetrated main fungus garden and one other. Two small supplementary gardens untouched, 60% of survivors were soldiers. No very young termites found alive.
Feeny with dust container attached	6	2	70	Alive	Very large nest about 2½ feet from surface. Numerous combs of varying sizes more or less blocked all the tunnels leading to main nest resulting in insufficient dust penetration to main nest. Failure undoubtedly caused through want of pressure in pump.
Feeny with dust container attached	3	2	75	Not found	This nest fumigated on 1st July and opened Aug. 13. Presence of eggs and young denote failure to kill the queen.
Feeny with dust container attached	6	1	90	Killed	Failed to kill all termites in portion of nest furthest from side where dust entered. Nest 2 feet from surface.
Feeny with dust container attached	7	2	99.9	Killed	Very large nest about 3½ feet from surface. Although a few ants found inside the queen's cell were not actually dead, they were incapable of doing more than kick their legs about feebly. Their bodies were discoloured. Nest opened three days after fumigation.
Feeny with dust container attached	6	1	100	Killed	Very small nest, about 1½ feet from surface.
Feeny with dust container attached	6	3	100	Killed	Very large nest, about 2 feet from surface.
Incledon	9	2	100	Killed	Pipe actually entered fungus garden, the top of which was only 1 foot from surface. Queen found 2½ feet from surface.
Incledon	8	3	100	Killed	Very large nest about 3 feet from surface.

(Fig. 7). These, however, are much more difficult to treat and great care should be taken in making the application.

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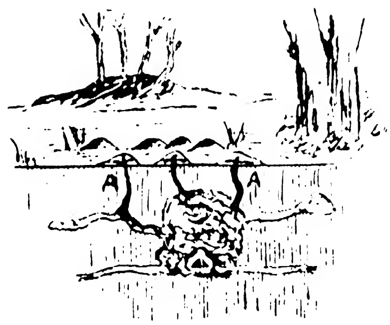
Fig. 5.—*Odontotermes badius.*



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Incledon	8	3	100	Killed	Very large nest about 3 feet from surface.

Odontotermes transvaalensis

The Chimney Maker, *Odontotermes transvaalensis,* is found principally in the Transvaal at the Pienaars River, Potgietersrust, Brits, Warmbaths, DeWildt, Klerksdorp, Potchefstroom, and Christiana. In Bechuanaland it is found at Vryburg. This is not a particularly destructive species as far as economic woods are concerned but it is a great nuisance in cultivated areas due to the caving in of the nests in wet weather. The soldiers are uniform in size and smaller than *Odontotermes badius* which they resemble closely. The main difference is in the fact that the right mandibular tooth is equal in size to the left in this species and not in *badius.* The upper margin of the mandibular tooth is at right angles to the jaw in this species (Fig. 8). The workers and soldiers may be found together in the funnel shaped galleries above the surface, the soldiers being somewhat larger.

Fig. 7.—Nest of *Odontotermes badius* in a Clump of Trees.

Fig. 8. *Odontotermes transvaalensis.*

The external nest consists of a number of slender funnels of irregular shape and height which taper from the base to the top, the opening being about an inch in diameter (Fig. 9). In summer during the rainy season the chimneys or funnels usually have somewhat wider tops. The galleries from these chimneys as a rule lead directly to the main part of the nest where the brood chambers and queen cell are situated. The nests may extend into the ground to as great a depth as eight feet.

To treat this type of a nest select one of the largest funnels for the main application. Before treating this opening blow two or three ounces of Cyanogas A-Dust down each of the other chimneys and close with wet earth. Treat the main opening by continually pumping for some time after the dosage has been applied in order to set up a circulation which will carry the dust itself to all parts of the nest. When treatment is finished the entrance should be closed.

Nests of *O. transvaalensis* can be very successfully treated by locating the main nest by means of a soil auger and using the method described for the treatment of *Termes latericius.*

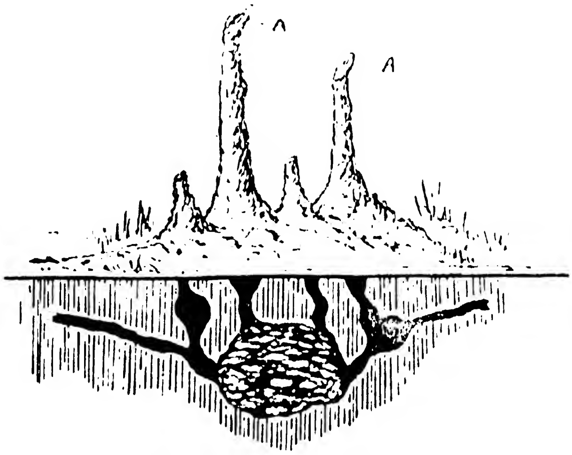


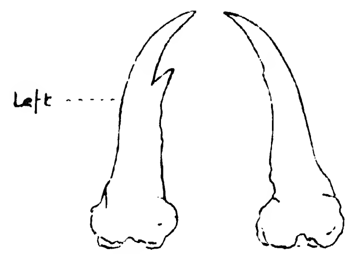
Fig. 9.—Nest of *Odontotermes transvaalensis.*

Termes latericius

The Pit and Funnel Maker Termite, *Termes latericius,* Hav. is found throughout Natal and in the Transvaal at Barberton, DeWildt, Pretoria, Groot Marico, Louis Trichardt, Narboomspruit, Pietersburg, Warmbath, and Johannesburg. The soldier caste members are uniform in size and fairly small, being no larger than the workers. Their heads however, are typically narrower and they are equipped for defense with fine, slender mandibles. (Fig. 10). The left mandible only has a fine, sharp tooth which is near the tip and directed forward. In one variety of this species the soldiers are relatively larger than the workers but are still small when compared to *Odontotermes badius.*

The feeding habits and external nest are similar to those of *Odontotermes transvaalensis.* It is a great pest of lawns where it mows down the grass and disfigures the surface by erecting clay canopies under which it works. The external nest consists of a number of chimneys of varying heights which as a rule are not so slender and taper less than do those of *transvaalensis.* The opening at the top is usually larger, being about three inches in diameter. The galleries from these chimneys do not run directly into the main nest but open into large chambers whose function is not quite clear but it is

thought that they are concerned with the aeration of the nest. (Fig. 11). During the mating season (Dec.-Jan.) the workers make large, oval, slanting runways direct to the surface from the nest to enable the fliers to escape easily. These galleries are open at the surface only when the fliers are on the move but can easily be located by scratching around the chimneys. In this species the soldiers are not found in the chimneys with the workers as in the case with *O. transvaalensis*.



Mandibles of T. latericius.

Fig. 10.

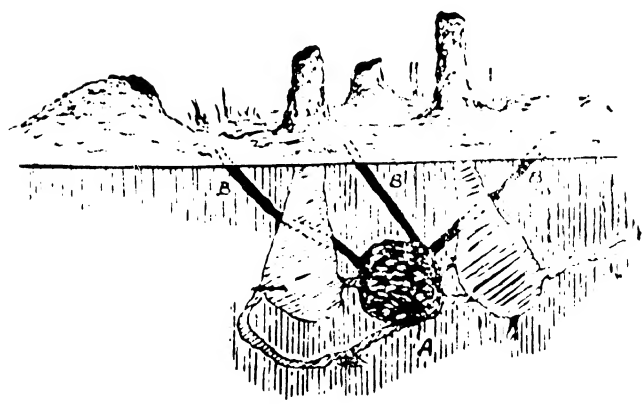


Fig. 11. Nest of *Termes latericius*.
Note Large Open Cavities Not Directly Connected to Nest.

In treating these nests with Cyanogas Calcium Cyanide, pumping the dust down the chimneys has generally given but poor results. The best method is to make application to the flier exits during the mating season. (B. of Fig. 11). Near the surface these openings are very small but on digging down for a short distance they open up more. Two or three ounces of Cyanogas A-Dust should be blown down several galleries on opposite sides of the nest. The pumping should continue for some time after the dosage has been discharged and the hole closed after treatment. The external size of the nest should be taken as a guide to how many openings should be located and treated and how great a quantity of dust should be used.

A second method of treating *T. latericius* consists of first pouring a little water down each chimney and then throwing in two or three ounces of Cyanogas. The chimney should then be sealed with mud for several days.

A third method is the use of a soil auger, somewhat after the fashion of the method used for *O. badius*. Before attempting drilling operations make a good survey of the number of chimneys; their sizes and the different positions at which they are situated. This done the largest chimney is selected, as this funnel, although never situated directly over the nest, is invariably about eighteen inches or two feet away from it. In the event of three chimneys being encountered in a triangular shape two will be smaller than a third. When treating, pierce holes about 18 inches to two feet away from the main chimney in a straight line with the smaller chimneys. The possibility is that during the drilling operations of the first hole, the auger will pierce the nest, indicated by the auger dropping suddenly into space as it pierces the brood-chamber. When this happen the auger is withdrawn and Cyanogas is blown down the hole drilled, which is then sealed with mud.

In the case of a small nest consisting of only two or three chimneys, it is unnecessary to drill more than one hole into the nest, but if the nest is large it is advisable to pierce the brood chamber from at least two points and blow dust down each hole to obtain good results. When a nest with twelve or more funnels is encountered two or three holes bored more or less in the center or the figure formed by joining the five largest chimneys, should pierce the nest.

TABLE IV

Experiments with *Termes latericius*

Pump Used	Dose in Ozs.	No. of Treated Openings	% of Brood Killed	Queen	Remarks
Feeny with dust container attached	6	2	0%	Not found	Small nest found 6 ft. from surface. This nest dug up about six months ago—Queen removed. Half charge went to old nest other half lodged in a solid lump in a tunnel leading to new nest—hence failure.
do.	6	2	0%	Alive	Nest 4 feet from surface. Holes pumped led away from nest.
Incledon	8	2	1%	Alive	Brood chamber 2 ft. from surface—3 very large channels leading down through two of which dust was pumped—led far below the brood chamber and only connected to it by a few very small tunnels. Had pumping been kept up longer, dust might have been forced up into brood chamber.
Incledon	8	2	40%	Alive	Queen found 2 feet from surface. Dust penetrated only upper portion of brood chamber.
Incledon	8	3	50%	Alive	Exceptionally large fungus garden about 2 ft. from surface. Dust failed to penetrate into brood chamber for more than 5/6 ins. Queen found actually in the process of depositing eggs. Great number of young winged termites in nest.
Incledon	8	3	75%	Alive	Nest 1½ ft. from surface. Failure due to lack of pressure from pump.
Incledon	7	2	80%	Killed	Nest 3 ft. from surface. Opened 5 hrs. after treatment. Strong odor of cyanide. Nest very hot. Kill would have been greater had nest been left unopened longer.
Incledon	8	2	100%	Killed	Nest 1½ feet from surface.
Incledon	6	2	100%	Killed	Large nest 3 feet from surface.
Incledon	8	3	100%	Killed	Nest 2 feet from surface.
Feeny with dust container attached	6	2	100%	Killed	Small nest about 3 feet from surface
do.	6	1	100%	Killed	Nest 3½ feet from surface.

Hodotermes Sp.

The Harvester Termites, *Hodotermes sp.* (Grasdraers) are numerous all over South Africa except along the Drakensburg and in the moist eastern seaboard of Natal, Pendoland, and Transeki. The soldiers are yellowish in color, heavy-headed and large-jawed. They differ from other species studied in that they have large eyes and powerful mandibles each of which has several large irregular teeth (Fig. 12). The soldiers seldom show themselves but mount guard in the nest and along the tunnels.

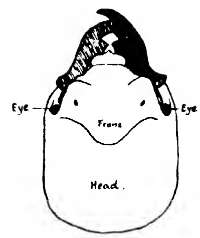


Fig. 12.- Typical Head of *Hodotermes sp.*

The name Harvester comes from the fact that the workers cut wheat oats, grass, corn, lucerne, etc. as they stand in the field. These they cut into short lengths which are then carried into the nest where they are placed temporarily in little pockets in the sides of the foraging tunnels. When dry these are taken into the main nest and used as a substratum in the termite fungus culture In some cases the crop is placed in ring shaped heaps near the entrance until dry and then carried piecemeal below the surface. When these pests are installed in buildings they do not attack the woodwork but eat up such light textured cellulose containing products as curtains, wall paper, etc. and tunnel through the walls making holes through which they eject unwanted material into the rooms.

When the nests are outside they are from two to eight feet below the surface of the soil. The main nest is a large cavity filled with hundreds of close set shelves of a brittle black substance of paper-like thinness. (Fig. 13). The only surface indication that there is a nest in the vicinity is certain small mounds, but these may be far from the nest as the runways are usually from twenty to forty feet in length and there are no direct connections between the surface and the nest. There are two types of galleries that lead to the solid surface; the foraging exits and the dump heaps. The foraging exits are those through which the workers drag grass and other provender, the dump heaps those from which soil is thrown. The latter are easily located by removing the soil from above them. The galleries open up somewhat below the surface but are never more than a half inch in diameter and are very difficult to follow up. Each nest has several queens but these are not confined in a clay cell as is the case with the other species studied. When this termite invades buildings the nest

is usually located under the building or may be in a mud brick in the walls or foundations. In DeGhoup of the Karro there is one species which makes its nest just below a hard clay mound. This is the only *Hodotermes* which makes an external indication of the spot beneath which the nest can be easily located.

When this species is found in the walls of buildings, blow the Cyanogas A-Dust into as many of the tunnels as possible. These should be closed after treatment. In the case of an outside nest it is a more difficult matter to make a thorough application. The foraging exits should never be treated as they are often blocked with chaff which renders penetration of the dust impossible. The small mounds should be cleared away and the larger runways located and followed up by digging until they open up sufficiently to allow application of the dust. A few ounces pumped forcibly into several of the galleries on opposite sides of the nest should be sufficient to cause extermination of the colony. The great distance of the nest from the point of application makes it necessary to apply the dust with considerable force and to continue pumping for some time after the charge has been delivered in order to insure a penetration of the dust to the uttermost parts of the nest.

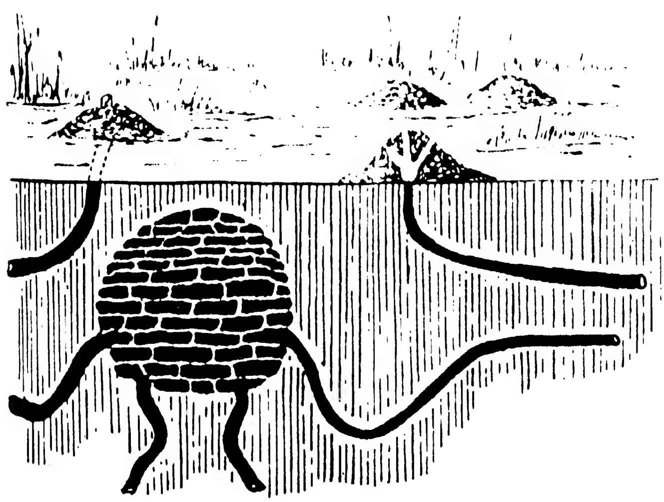


Fig. 13.—Nest of *Hodotermes sp.*

Conclusions

It is possible to treat termite nests with Cyanogas Calcium Cyanide A-Dust and to secure a high percentage of kill that will result in the extermination of the colony. The main factor in successful treatment is to make a thorough application of the material in order to secure a penetration of the dust to all parts of the nest, especially the brood chambers and queen cell. As the various species construct different types of nests it is advisable to determine the species being treated or at least to determine the type of nest being considered so that advantage can be taken of its peculiar structure to insure application at the most advantageous points. In treating the nests better results are obtained if openings on opposite sides of the nest are treated and the pumping continued for a short time after the dosage has been applied. All holes from which dust is seen to emerge and all treated holes should be closed.

Literature Cited

1. Jarvis, E.—"Cane Pest Combat and Control." Queensland Agric Jl., xxvi, pt. 1, pp. 47-50. Brisbane, July 1926.
2. ...... "Cane Pest Combat and Control." Queensland Agric. Jl. xxvii, pt. 2, pp. 85-88 Brisbane, February 1927.
3. Brittain, W. H.—"Calcium Cyanide and its Utilization in the Control of Insect Pests in Ceylon."—Trop. Agriculturist, lxvii, No. 1, pp. 45-48. Peradeniya, July 1926.
4. Jepson, F. P. "Some Preliminary Notes on Tea Termites."—Trop. Agriculturist, lxvii, No. 2, pp. 67-79. Peradeniya, August 1926.
5. Patterson, W. H.—"Annual Report of the Government Entomologist." Gold Coast: Rept. Agric. Dept. 1925-1926 pp. 36-38. Accra 1926.
6. Brittain, W. H.—"Calcium Cyanide and its Utilization in the Control of Mound-Building Termites or White Ants."—Bengal Agric. Jl., Vol. 5, Nos. 3 and 4, pp 82-87. Dacca, 1925.
7. Snyder, T. E.—"Preventing Damage by Termites or White Ants."—U. S. Dept. Agric., Farmer's Bull 1472. Washington, D. C., April 1926.

Issued June 29, 1927.

SECTION 5

FUMIGATION—SOIL

Fumigation Soil

One phase of insect control which has been more or less baffling to entomologists in the past has been the absence of a simple remedy for soil-infesting pests. Information already available would indicate that Cyanogas Calcium Cyanide is peculiarly valuable for this type of control work. The material is acted upon by the soil moisture and the lethal hydrocyanic acid gas permeates the soil and kills the insect. Since the residue is lime and certain nitrogenous products which are valuable as plant food, the residual effect on the soil is beneficial.

PRELIMINARY EXPERIMENTS

The value of Cyanogas Calcium Cyanide as a soil fumigant was early recognized by Professor H. J. Quayle. Some of his preliminary experiments published in the Journal of Economic Entomology have been reproduced on page 1-6. Another report of his work, published in the Report of the College of Agriculture and the Agricultural Experiment Station of the University of California, 1922-23, is given below.

Soil Fumigation with Calcium Cyanid.—Tests with calcium cyanid in flake and dust form made by H. J. Quayle and H. Knight assisted by F. C. Greer, indicate that this material is well adapted to soil fumigation.

Wooly aphis and other soil infesting insects have been killed by the use of 2 ounces to the square yard. Better results were obtained in dry than in moist soil.

In October, 1922, soil around the base of apricot trees was treated with dust, using from 2 to 5 ounces to a tree. No signs of injury have been observed. The trees appear vigorous and have set a good crop of fruit.

Satisfactory results against the peach tree borer have been obtained with 2 ounces of dust to the tree, applied directly to the trunk and well covered with dirt. No injurious effects to the trees have yet been observed.

Early experiments in the use of Cyanogas Calcium Cyanide as a soil fumigant for control of the Pear Thrips, *Toeniothrips pyri* Daniel, and the Apple Maggot, *Rhagoletis pomonella*, Walsh, by Professor F. G. Mundinger have already been reproduced on pages 6-6 to 6-8.

THE PEAR LEAF MIDGE

A series of interesting experiments have been conducted on the control of the Pear Leaf Midge, *Perrisia pyri*, in New Zealand, by David Miller, Entomologist, Biological Laboratory, Wellington, New Zealand. The following reprint is the section of his paper dealing with control measures and is taken from "The Pear Midge, Further Observations and Control with Calcium Cyanide", The New Zealand Journal of Agriculture, Vol. XXX, No. 4, April, 1925, p. 220.

CONTROL WITH CALCIUM CYANIDE.

Owing to the pear-midge larvæ when on the trees being protected by the rolled-up leaves, none of the sprays tested have been sufficiently effective. However, the habit of the larva entering the ground to hibernate and pupate presents an opportunity for control.

Though a number of insecticides have been experimented with in soil-treatment (*Journal*, August, 1921), no results of a practical value were obtained until the present season, when calcium cyanide was used. This is a preparation manufactured by the American Cyanamid Company, New York, and at the time of these experiments was prepared in three forms—granules, flakes, and dust. Owing to later improvements in the manufacturing processes, however, the granules can now be made at less cost and placed on the market at the same rate as formerly charged for the flakes, which have been withdrawn. On the cyanide being exposed to the atmosphere, hydrocyanic-acid gas is generated, and its value as a soil-fumigant is at once apparent. The opinion has been put forward that too great a danger to life is involved by the use of this material, but that is by no means so if ordinary common-sense is used in its handling. Certainly the danger is comparatively small when the cyanide is used out of doors.

In the following experiments against one of the summer broods of midge, carried out at Mr. F. G. Platts's orchard at Henderson, the granular cyanide was used. Six dosages were laid out, each involving three plots of infested soil under as many trees, making a total of eighteen trees treated. Over the treated area under each tree two emergence tents were pitched, so that six observations were made for each dosage. As a check twelve tents were pitched under untreated trees. Owing to lack of sufficient cyanide the experiments were not made more extensive.

The dosages of cyanide to each area of 200 sq. ft. were as follows, the material being spread on the ground and worked, not turned, in with a spade: (1) 2 lb., (2) 1¾ lb., (3) 1½ lb., (4) 1 lb., (5) ¾ lb., (6) ½ lb.

An examination of the emergence tents at the time when the midges were due to emerge showed that the efficiency of the cyanide divided the dosages into two groups, one comprising dosages (1), (2), and (3), and the other the dosages (4), (5), and (6). In the first group there was 100 per cent. control, and in all of the second group but little control, if any. Certainly the weakest dosages, (5) and (6), cannot be claimed to have had any effect, since the numbers of midges emerging into the tents over these plots could not be said to be any less than those in the check tents.

Owing to results between the two groups of dosages—(1), (2), (3) and (4), (5), (6)—being so decidedly positive and negative, a later attempt was made with dosages of strengths each descending by 1 oz. from 1½ lb. to 1 lb. to every 200 sq. ft. of infested ground. In this experiment, carried out to determine if there was a weaker effective dosage between (3) and (4), thirty-six observations were made, exclusive of checks. Nine dosages, each involving infested ground under two trees, were applied. On each of these eighteen plots an emergence tent was pitched, together with an emergence box. This latter, turned mouth downwards, measured 10 in. (high) by 14 in. by 20 in. (inside measurements), and was lined with black paper. On the top five holes were bored, in each of which was inserted a glass tube 1 in. in diameter and open at both ends except for a muslin cap over the outer one. A cork fitted with a narrow tube was inserted into the opposite end within the box, in order to prevent any midges from leaving the tubes once they had entered. It was hoped by this means to make counts of the midges emerging from each dosage, but the moisture which collected in the bottom of each tube interfered with this.

The results of these experiments, however, as gauged from the tents, showed that the dosage of 1½ lb. to 200 sq. ft. was the weakest effective strength that could be used for 100 per cent. control. Acting on this basis it is intended to extend the work on a larger scale, treating whole orchards under commercial conditions in order to test the efficiency of the cyanide against the hibernating midge-larvæ. A point of interest in the experiments was that though the pear-midge was controlled by the stronger dosages, the latter had apparently no effect on certain other underground insects, since there was a general emergence in all the tents of such insects as the cicada (*Melampsalta cingulata*), and several ichneumon flies and muscid flies.

The quantity of cyanide required to treat a midge-infested orchard will vary with the spread of the trees. In mature orchards where trees

overlap, the full acreage must be treated at a maximum cost, but with upright mature varieties or younger trees less cyanide will be required, until a minimum is reached in a newly planted orchard or in a nursery. It is not known at present just what the exact cost of treatment with calcium cyanide would be, but in any case the results here recorded, together with the reduced price of the granules, show that at least young orchards (or even some mature ones) and nurseries, where isolated, could be economically treated at present.

That ordinary winter cultivation, if carefully carried out, will reduce the numbers of midges emerging in the spring has been proved (*Journal*, August, 1921), but no concerted attempt has been made to follow this line of treatment, which requires that orchards be well kept throughout the year, so that the thorough turning-in of the midge-infested surface soil is made possible during the insect's hibernating-period. Not only is the pear-midge so reduced in numbers, but also other insects hibernating underground.

Wireworms

Wireworms, the larvae of various species of Elateridae, have been a source of worry and embarrassment to entomologists since the establishment of Economic Entomology as a profession. Because of the subterranean mode of life of the larvae, they were difficult to attack. When one reviews the literature pertaining to this pest he finds that poisoned baits, repellants, and cultural practices were all thoroughly investigated and in turn discarded as worthless It is true that certain liquid fumigants had been shown to possess killing properties when applied to wireworms but these were never adopted by the grower because of commercial impracticability. A thorough investigation, during the past three years, has demonstrated the value of Cyanogas Calcium Cyanide for wireworm control both from the standpoint of efficiency and from the standpoint of commercial practicability.

COMMERCIAL IMPORTANCE

A large variety of field and vegetable crops are subject to attack by wireworms as they feed during their three years or more spent as larvae in the soil. Corn, wheat, oats, alfalfa, potatoes, sugar beets, lima beans, tobacco, melons, nursery seedling stock, and truck crops in general furnish food for the various species indigenous to various parts of the world. In the case of some of these crops such as tobacco, beets, early cabbage, wheat and parsnips, feeding of the wireworms may so damage the roots that the plants die or are stunted and unmarketable. In the case of other crops such as potatoes and carrots the feeding of the wireworms reduces the marketable value of the crop so that it is thrown out of the top grade or cannot be marketed at all. In a single county of the state of Washington during the year 1922, it has been estimated that the losses to potato growers due to wireworm damage amounted to over \$360,000. In the same state the annual losses suffered by the nurserymen of such seedling stocks as Japanese pear, apple and cherry have been placed at \$5000. per acre.

In California it has been estimated that over one million acres of land, devoted to production of such crops as lima beans, sugar beets, etc., are infested. An instance is on record of the destruction of 40 acres of shade grown tobacco plants in the Connecticut valley on a single farm with the necessity for discing and replanting with attendant shortening of the growing season. Such instances are cited merely to indicate that the problem of wireworm control has been a serious problem in many sections of the United States.

FIG. 1.—Screening to Determine Depth of Wireworms in Soil—Azusa, Calif.

SPECIES CONCERNED

Several species of wireworms are responsible for the losses which have been mentioned. *Phletes occidentalis* is found in the Yakima Valley and some other irrigated sections of the Western United States. *Phletes californicus* is the important species in California. *Ludius noxius* is the species found in the arid or dry land sections of Washington. In the Connecticut Valley and Eastern United States the common destructive form is *Limonius sp.* probably *L. agonus*. In the Piedmont Section of the Carolinas, *Aeolus dorsalis* is often destructive. In England the species occurring in greatest numbers as a pest, is *Agriotes obscurus L.*

EXPERIMENTAL WORK

Experimental work with Cyanogas Calcium Cyanide as a soil fumigant for control of wireworms was started in the Spring of 1923. Some of the early experiments in the Eastern United States were carried on by Dr. J. L. Horsfall at the Research Laboratory of Pennsylvania State College, Philadelphia, Penna. These experiments established the fact that Cyanogas Calcium Cyanide would kill wireworms but that it was not possible to obtain satisfactory control without serious injury when applied directly to growing crops. An account of these early experiments was published by Dr. Horsfall in the Journal of Economic Entomology, Vol. 17, No. 1, February, 1924, p. 160.

Possibilities of Granular Calcium Cyanide as a Control Measure for Wireworms. Severe infestations of wireworms occurred during May and June, 1923, in fields of early cabbage near Philadelphia. Losses varied from 15% to 49% of the entire stand. In some fields as many as 25 individuals were taken from the roots of a single plant. Neither poison bran bait nor corrosive sublimate solution, 1–1000, resulted in control.

Wireworms were confined in pots of moist soil one, two, three, and four inches below the surface. Five individuals were used in each experiment. Five grams of granular calcium cyanide were placed on the surface of the soil in each pot. When examined after a 48-hour period, one hundred percent kill was found to have been obtained in each of the treated pots while all individuals in the checks were living. The same treatment was then applied in one section of a heavily infested field of cabbage. Six to eight grams of granular calcium cyanide were placed three inches from each plant in a furrow left by cultivation. In some rows, dirt was thrown over the cyanide with a wheel hoe, in other rows the material was left exposed. Within twenty-four hours, the field was watered by an overhead system of irrigation. Five days after application, the plants were examined and an average of 81% kill was found to have been obtained. Twenty dead wireworms and one live individual were taken from one root. No difference in kill was found between the rows in which the material was covered and those in which it was left uncovered. A strong odor of cyanide was distinguishable in the soil five days after treatment. Some injury to the plants resulted from this treatment which may have been due to weakened root systems. Tests to determine the tolerance of plants to various dosages were repeated four times on plants which had been transplanted two weeks and which were not infested with wireworms. No injury resulted from dosages of 5 grams to 10 grams per plant. Plants, treated with 12, 14, and 16 grams respectively, were killed.

J. L. Horsfall,
Pa. Sta. Col. Laboratory, Bustleton, Pa.

Mr. Roy E. Campbell of the U. S. Bureau of Entomology started experiments in the control of wireworms in California and Washington during the summer of 1923 using the broadcast and prebaiting methods. Various machines were also tested as to their usefulness in making applications of the Cyanogas Calcium Cyanide. The results of these early tests formed the basis for a paper by Mr. Campbell which appeared in the Journal of Economic Entomology, Vol. 17, No. 5, October, 1925, p. 562.

PRELIMINARY REPORT ON THE USE OF CALCIUM CYANIDE AS A SOIL FUMIGANT FOR WIREWORMS

By Roy E. Campbell, *U. S. Bureau of Entomology, Alhambra, California*

Abstract

In a series of preliminary pot and field experiments calcium cyanide, used at the rate of from 130 to 400 pounds per acre, showed a decided toxicity to wireworms, Elaterid larvae, and indicated that about 200 pounds per acre if properly applied would kill 75 per cent, or more, of the worms.

Wireworms[1] have caused enormous damage to various crops on the Pacific coast for a number of years, particularly to beans, beets, and potatoes, but to many other crops as well. Many attempts have been made to control these pests, but none has proved satisfactory. One entomologist expressed his opinion that "wireworm control is a problem which we can leave for posterity to solve." With the constantly increasing damage from wireworms, however, it is becoming apparent that the discovery of some method of control can not wait on posterity.

It has long been known that hydrocyanic-acid gas derived from sodium or potassium cyanide would kill wireworms, but its use was impractical because of its high cost and its injury to plant life. The development of the low-grade and comparatively cheap calcium cyanide removes the first objection to the use of hydrocyanic-acid gas, and the use of the material when the ground is fallow, or prior to planting, eliminates the second objection.

In order to test the effect of Calcium cyanide on wireworms, a series of experiments was undertaken in the laboratory at Alhambra, Calif., in

[1]The species principally concerned are *Pheletes californicus* in Calif. and *P. occidentalis* in Washington.

June, 1923, 10-inch pots of soil being used, followed, in August, by field tests at Toppenish, Wash.[2]

In the pot experiments, various types of soil were used, as well as moist, dry, loose, and packed soil, and the relative locations of the cyanide and wireworms were also varied. A summary of all of the experiments show the following:[3]

TABLE I SHOWING PERCENTAGE OF WIREWORMS KILLED BY DIFFERENT AMOUNTS OF CALCIUM CYANIDE DUST PER ACRE IN POT EXPERIMENTS AT ALHAMBRA, CALIFORNIA, IN 1923

Pounds per acre	Per cent killed Maximum	Minimum	Average	Number of experiment	Total number of worms used
400	100	70	92	9	90
350	100	30	80	12	120
300	100	30	71	12	120
250	90	30	65	12	120
200	100	10	50	13	130
150	90	0	40	11	110
Control[4]	10	0	1	9	90

Although nearly a hundred experiments were performed, they were not considered sufficient to explain entirely the variations in results. An analysis of the experiments, however, suggests the following factors as having a bearing on the success or failure resulting in several cases:

(1) DEPTH OF CYANIDE. Following shallow applications, there remained in the pots a considerable percentage of live worms, nearly all of which, except in the case of light dosages, were several inches below the cyanide. It was therefore concluded from the rather meager evidence that the killing of few wireworms below the cyanide could be expected.

(2) MECHANICAL CONDITION OF THE SOIL. In experiments where the soil was left very loose, the killing in most cases was low, probably owing to the fact that the gas was allowed to escape too rapidly. Where the soil was packed hard, also, the killing was low, owing to the difficulty with which the gas penetrates soils in this condition.

(3) ACTIVITY OF THE WIREWORMS. As the experiments continued into the fall and the wireworms became less active, results showed

[2]The experiments at Toppenish were carried on under the writer's direction by Mr. John N. Stone.

[3]In these experiments calcium cyanide dust was used, while for field work the granular form was used.

[4]Of the 90 worms used in the controls, 86 were recovered, 85 alive and 1 dead. However, in none of the experiments were missing worms considered as having been killed. In computing the percentage of killing, only the dead worms actually recovered were used.

lower killing, even with the higher dosages. It may be that as the wireworms become less active the effect of the gas upon them decreases.

Results obtained at Toppenish, Wash., gave considerable promise, but difficulties were encountered owing to the lateness in the season, the hardness of the soil, and the increasing inactivity of the wireworms. Benefited by the experience gained in the fall, the experiments were begun at the first signs of wireworm activity in the spring, which was early in March. A special machine was designed by the American Cyanamid Company which could be attached to the beam of a plow and set to feed a definite amount of cyanide in the furrow just ahead of the soil which is being turned over. Disc and hoe drills also were used in the application of calcium cyanide. Soil examinations were made both in the plots and in other parts of the infested fields. The percentage of killing was ascertained by sifting several cubic feet of soil in each plot and counting the dead and live insects. A summary of the experiments up to May 5 shows the following results:[5]

TABLE II.—SHOWING PERCENTAGE OF WIREWORMS KILLED BY DIFFERENT AMOUNTS OF GRANULAR CALCIUM CYANIDE, TOPPENISH, WASHINGTON

Pounds per acre	Per cent killed Maximum	Minimum	Average	Number of experiments	Total number of worms found
350–500	100	100	100	4	35
280–300	100	71	93	6	141
225–250	100	77	89	5	58
180–200	100	21	73	11	335
130–150	81	16	49	8	154
Control	0	0	0	21	579

Here again it is at present impossible to explain the variations in results but a study of the experiments suggest several contributing factors, among which are the following:

(1) TEMPERATURE. During low temperatures the wireworms are inactive and probably not so greatly affected by the gas as when active.

(2) MOISTURE. In several of the experiments where poor results were obtained the soil was wet. It is well known that moisture will absorb hydrocyanic-acid gas and that when too much moisture is present the calcium cyanide breaks down, forming ammonia and thus lessening the amount of hydrocyanic-acid gas given off. Probably this is what happened in some of these experiments.

(3) METHOD OF APPLICATION. In most cases better results were

[5]The type of soil at Toppenish is volcanic ash loam, and was practically uniform in all plots, varying only in its mechanical condition.

obtained with the drill, which placed the cyanide in the soil in rows 6 or 8 inches apart, than with the plow applicator, which placed the cyanide in rows 14 to 16 inches apart.[6]

(4) TEXTURE OF SOIL. Too loose or too compact a soil also seemed to be the cause of poor results.

(5) DEPTH OF APPLICATION. This appears to be very important, for equally poor results were obtained when the cyanide was placed too near the surface and when it was placed too deep. The depth at which the majority of the wireworms occur seems to determine the proper depth for applying the cyanide. This depth appears to vary throughout the season but the habits of the worms have not been sufficiently studied so that it can be predicted with certainty. In most of the experiments, however, the best results were obtained when the cyanide was applied from 4 to 6 inches deep.

The experiments so far have not determined whether it is best to apply the material early in the season, or as late as possible, just prior to planting, but indications are that late spring will be the best time. In early spring the worms are not only more or less inactive, but are fairly deep in the soil. When the soil warms up they become quite active and feed near the surface, but with the advent of hot summer weather, they go deeper in the soil again. Screening of a number of one-foot cross sections of soil in the last of February showed that 46 per cent of the worms were in the upper 4 inches, 40 per cent from 4 to 6 inches deep and 14 per cent from 6 to 8 inches. On May 5, however, 73 per cent of the worms were in the upper 3 inches and 90 per cent in the upper 4 inches.

During cold weather worms turned up by the plow show very little activity, remaining at the surface, often exposed for some time, but in warmer weather such worms rapidly work back into the soil. In the Yakima Valley early applications also killed many adults which had not as yet emerged from the soil.

To determine how long the cyanide remained in the soil, definite applications followed by chemical analyses were made, with results as follows: No cyanide could be detected in a wet soil[7] after 2 days when 150 pounds per acre had been applied and none after 4 days following an application of 500 pounds to the acre. In a dry soil[7] a faint trace of cyanide could be detected on the fourth day after using 150 pounds per

[6]The use of the applicator on 8 or 10-inch bottom plows, or with a spreading device, would remove this difficulty.

[7]The wet soil had more and the dry soil less than the optimum amount of moisture for cultivation or planting.

acre, and on the tenth day when 500 pounds per acre was used. The quantity toward the end of the period was extremely small in each case. These data indicate that the cyanide remains in the soil for only a short time, and that it will be perfectly safe to do the planting within a week or 10 days after application. These results have been confirmed by field experiments. Seed potatoes planted immediately or the next day after a calcium cyanide application were all injured, but when planted a week or more after the application they showed no effect from the cyanide.

The application of calcium cyanide to soil in which plants, such as potatoes, bulbs, and young seedling trees, were growing, demonstrated that when it was placed close enough to the plants or used in quantities sufficient to get a good killing of wireworms, injury to the roots or tubers resulted.

On only one experimental plot are the plants sufficiently advanced in growth at this writing to show the effect of the treatment on the crop. A treated potato plot on badly infested soil shows a decidedly better stand and growth than the untreated adjoining areas. This not only indicates that the wireworms were controlled, but also that the calcium cyanide did not injuriously affect the soil for subsequent plant growth. Practically all plots have been planted to some crop, and examinations will be made during growth and at harvest to determine how effective the treatment has been in increasing the quantity or improving quality.

The experiments so far have been intended primarily to determine whether calcium cyanide will kill a satisfactory proportion of the wireworms when applied in moderate amounts. They indicate that 200 pounds per acre if properly applied will kill 75 per cent, or more, of the worms at a cost of about \$30 per acre. It should be borne in mind that the benefit of one treatment will extend over two or three years at least,[8] owing to the fact that it requires about three years for these wireworms to reach maturity and a single brood may cause injury over this period.

Experiments are now under way to discover means of reducing the amount of cyanide required per acre and thereby the cost of treatment. It is a well-known fact that wireworms collect in the rows of beans or other crops, therefore, if advantage is taken of this habit by drilling in split beans, rice bran, or other attractants, to induce the wireworms to concentrate in rows 2 or 3 feet apart, and subsequently treating these rows with a fairly heavy application of cyanide, a better killing may be

[8]In addition to controlling the wireworms, there is some evidence that the use of calcium cyanide increases the nitrogen content of the soil.

obtained with less material per acre. Improvements in methods of application are also under way, as well as experiments to ascertain the proper depth of application, distance between treated rows, best time to apply the cyanide, etc.

The calcium cyanide used in the field experiments was the granular form, which is the ordinary flakes ground to about the fineness of coarsely ground coffee and the finer particles sifted out and discarded. This material feeds readily from grain and small seed drills, is more conveniently handled and applied and appears to give better results than the finely ground dust.

The following article by Mr. Anthony Spuler is interesting because of the data which is given on the effectiveness of various bait crops. He also includes the results which were obtained by treating various baits with Cyanogas Calcium Cyanide after wireworms had been attracted to these baits. Mr. Spuler's paper is reproduced from the Journal of Economic Entomology, Vol. 18, No. 5, October, 1925, p. 703.

BAITING WIREWORMS[1]

By ANTHONY SPULER, *Washington Agricultural Experiment Station, Pullman, Wash.*

ABSTRACT

Calcium cyanide is an effective soil fumigant for the wet land wireworm, *Pheletes occidentalis*, but it is too expensive. Baits concentrate wireworms and when used in soil fumigation decrease the cost of treatment. Germinating seeds attract more worms and are more easily planted than other forms of baits.

The irrigated or wet land wireworm (*Pheletes occidentalis*) is fast becoming one of the most destructive insects to garden and field crops in the irrigated sections of the state. Soil examinations show that in areas reputed to have severe infestations the wireworm population varies from about 80,000 per acre at Toppenish, Wash. to 400,000 at Clarkston, Wash. Because of this severe infestation requests for practical means of control are becoming more persistent year by year.

Considerable work has been done on soil fumigation as a control for wireworms. Experiments conducted by Tattersfield and Roberts of Rothamsted, England, Dr. William Moore of the American Cyanamid Co., J. E. Neiffert of the U. S. Bureau of Chemistry and others show that there are a number of toxic substances that will kill insects of this type. Most of these fumigants will not lend themselves to soil conditions and can therefore not be used as soil fumigants. To be a good soil fumigant a material must have all or most of the following qualities: 1st, It must be highly toxic to insects: 2nd, it must not be dangerous to handle: 3d, it must not be readily adsorbed or broken up by the soil: 4th, it must not be unduly toxic to plants and 5th, it must not be ex-

[1]Contribution Number 122, Wash. Ag. Exp. Station, Pullman, Wash.

pensive. When these tests are applied to the various substances used in insect control all are found wanting. The one material that comes nearest meeting these tests is calcium cyanide. Calcium cyanide, however, is toxic to plants and altho the present price is as low as 15 cents per pound, is still too expensive to find general favor among the farmers. Recent investigations at Toppenish, Wash. have shown that at least 300 pounds of calcium cyanide are required to kill a high percentage of the worms in the soil under favorable conditions. This would cost 45 dollars per acre which is still too much of a tax to be considered by the farmer.

In June of 1923, investigations were carried on by the Division of Entomology of the Washington Experiment Station to determine if soil fumigation could not be supplemented by the use of baits in the control of the wet land wireworm. It has long been known that the Japanese gardeners depend on rice bran or rice flour baits to attract the worms away from the growing vegetation and to concentrate the worm to small areas where they can be dug up and destroyed. If the worms could be attracted from some distance in the soil the need for fumigating every foot of soil would be eliminated and the cost of treating the soil reduced. Accordingly various types of baits were planted in the soil among young nursery trees of the Washington Nursery Co. at Toppenish, Wash. The trees were at that time badly infested with wireworms and many of them had been killed outright. The baits were placed between the rows of trees and spaced four feet each way, thus forming the center of a circular area of about 12 square feet. After a period of a week the baits were examined for worms. The following table shows the results obtained in the use of the various baits:

Table 1. Results Obtained from Various Baits

Bait used	Av. No. worms per bait	Bait used	Av. No. worms per bait
Rice flour	26.6	Bran	22.5
Graham flour	26.6	Potatoes	17.3
Graham flour and sugar	24.5	Carrot roots	15
Graham flour and oranges	21.9	Carrot tops	8.4
Graham flour and lemons	20.1	Apples	8.4

The flour and bran baits were prepared by adding sufficient water to the flour to make a stiff dough. Since the original infestation in the nursery plot was found to be about two worms per square foot of soil, it seems that some of the baits proved quite effective in concentrating the worms.

In June of 1924 further investigations in the use of baits were carried on at Toppenish, Wash. by Mr. J. N. Stone of the American Cyanamid Co. and the speaker. A sugar beet field was used for the experiment. Prior to this time the field had been in beets but was plowed up because so many of the beets had been destroyed by the wireworms that only a few scattered beets were left. It was thought that this ground, because of its severe infestation, would prove ideal to try out baits. This did not prove to be the case. The freshly plowed ground dried out quickly and difficulty in getting irrigation water on the ground caused the worms to seek lower levels. The beet roots as well as tops that were turned down by the plow served as baits for the worms and fresh bait placed in the ground would not attract the worms away from the beets. In this experiment seeds of peas, beans and corn were planted in rows spaced six feet apart, by means of a garden seeder. Notwithstanding the fact that the beets themselves served as baits, many worms were attracted to the germinating seeds. It was thought, however, that many more would have been attracted had it not been for the beets which served as a counter attractant.

Wireworms are very fond of germinating seeds and will attack most garden vegetables while in that stage. For this reason any treatment of the soil would be most effective if applied before the regular garden or field crops are planted. In order to determine how early in the season this could be done, investigations were conducted at Clarkston, Wash. this year, beginning February 23. At this time most of the early garden in the vicinity had been planted but the soil was still cold and the wireworms inactive. None of the worms were found in the upper eight inches and very few were found in the upper twelve inches of soil.

Thru the courtesy of Mr. M. V. Pound of Clarkston, a plot of ground that had been used to grow a home garden for 26 years, was secured. Examination of the soil showed an infestation of approximately eleven worms to the square foot of soil. On February 23 Alaska field peas, garden beans and sweet corn were drilled in rows, spaced six feet apart, by means of a garden seeder. One row each of graham flour and potatoe baits was planted to check on the efficiency of the germinating seeds as baits. The graham flour and potato baits were spaced four feet each way.

Subsequent examination of the baits showed that the corn and beans did not germinate until March 13th and that wireworms activity did not commence until March 27th. When the wireworms did finally become active and work toward the upper few inches of soil, most of the

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corn and bean seed had rotted. The Alaska field peas germinated early and the young plants were about two inches high and past the most attractive stage for the worms when worm activity began.

It was not until two weeks later that all the worms seemed near the surface. At this time all the baits were treated with calcium cyanide. Fifty pounds of calcium cyanide per acre was drilled in on one row by means of a garden seeder, but the garden seeder proved unsatisfactory since it did not place the cyanide deep enough in the soil to do effective work, so the remaining rows were treated by plowing a furrow close to the row by means of a hand plow. Where the hand plow was used the calcium cyanide was sprinkled in the bottom of the furrow at the rate of 100 pounds per acre and immediately covered by the plow. Where the graham and potato baits were used fumigation consisted in punching a hole in the soil over the bait by means of a hoe handle and placing one tablespoon full of calcium cyanide in each hole. The treatment of the graham flour and potato baits, as well as those rows of seedlings that received 100 pounds of cyanide per acre, proved to be 85% to 95% effective. The one row receiving but 50 pounds of calcium cyanide was only from 50% to 80% effective. Much of the poor showing in the case of the one row was probably due to the fact that the seeder did not place the cyanide deep enough in the soil. Four days after treatment with calcium cyanide, counts were made to determine the number of worms that had been caught at the baits. Similar counts from soil between the rows at this time indicated that all of the worms had not been attracted to the baits. To determine the number of worms not attracted by the first series of baits a second series was planted between the rows of the first. A week later the second series of baits was treated and checked. The following table shows the results obtained in the two series of baits used:

TABLE 2. AVERAGE NUMBER OF WORMS ATTRACTED PER SQUARE FOOT OF BAIT

Bait used	1st series	2nd series	Total	Worms per sq. ft. in soil after baiting
Alaska peas	43	19	62	2
Beans	41	20	61	1
Corn	43	22	65	1
Graham flour	75	—	75	4
Potato	22	—	22	7

The graham flour and potato baits were not renewed and that portion of the plot received but one series of baits. From this table it would seem that a high percentage of worms can be attracted to baits. The first series of baits would undoubtedly have attracted more worms had

they been in prime condition when wireworm activity was at its height. Had the first baiting been deferred until all wireworms were in the upper few inches of soil it is quite probable that further baiting would not have been necessary.

Baits for wireworms are most effective when planted during the height of wireworm activity. This is after the early garden is planted and before the soil becomes too warm near the surface to enable the wireworm to thrive in the first few inches of soil Any plot of ground to be treated by baits in connection with calcium cyanide or with calcium cyanide alone must be used for some late crop such as potatoes. It is necessary when baiting a field to have it free from weeds or other vegetation, since this wireworm relishes such weeds as the Russian thistle and mustard. Baits should be allowed to remain in the soil for some time before treating with cyanide. It was found that more worms were attracted at the end of two weeks than after one week. One graham flour bait which had attracted 114 worms after two weeks attracted 45 more in another week. Calcium cyanide acts as a repellent and any bait so treated will cease to attract the wireworm.

The cost of baiting a field is not great. Two men can easily cover a field of five acres in a day. One hundred pounds of calcium cyanide is sufficient to treat an acre of soil where baits have been used. Germinating seeds prove to be the most efficient bait since they take less time to plant and attract more worms per foot than do the flour or potato baits.

The experimental work in England has been conducted by Mr. Herbert W. Miles, one of the research entomologists of this company.

OBSERVATIONS ON WIREWORMS AND THEIR CONTROL IN ENGLAND WITH CYANOGAS CALCIUM CYANIDE

By

Herbert W. Miles, M.Sc. (Bristol), N.D.A.

Introduction

Wireworms are a particularly serious pest in land which has been newly broken up, and for the first three or four years afterwards are responsible for considerable losses, especially to such crops as potatoes, wheat and oats. Where land is enclosed for market garden work young vegetables are particularly liable to severe damage and each year much loss is caused by wireworms to tomatoes under glass. From time to time various substances have been recommended as a soil dressing to control wireworms but no really satisfactory treatment has so far been forthcoming. The manufacture of Cyanogas Calcium Cyanide and its availability in a granular form suitable for use as a soil fumigant suggested that, provided a technique could be worked out, this substance might furnish a better control of wireworms than any so far employed. In 1923, work was carried out on the Cyanogas Calcium Cyanide treatment in America by Campbell (1), who conducted pot experiments in California and field tests in Washington. From these tests it was concluded that used at the rate of 130 to 400 pounds per acre, Cyanogas Calcium Cyanide showed a decided toxicity to wireworms of the species *Phletes californicus* and *P. occidentalis* and that 200 pounds per acre if properly applied would give 75% or more control. In 1924, experiments were conducted (2) in Washington on the use of baits in conjunction with the Cyanogas Calcium Cyanide treatment for wireworms since it was thought that the attraction of the wireworms to the vicinity of the baits would reduce the amount of Cyanogas Calcium Cyanide necessary for control and thereby lessen the cost. The results justified the experiments for it was found that the baits concentrated the wireworms and decreased the cost of soil fumigation. It was also found that germinating seeds attracted more wireworms and were more easily planted than any other forms of bait.

1. Campbell, page 5-8 2. Spuler, page 5-13

In 1925 work was commenced to discover if the methods employed in America could with equal success be adopted in England and the investigations so far indicate that in Lincolnshire prebaiting, followed by the application of Cyanogas Granular Calcium Cyanide, will give effective control of wireworms.

Soil and Climate.

The experiments were conducted at Boston, Lincolnshire in a field four acres in area ploughed out of grass in the early spring of 1925. The land had carried a crop of early potatoes which were to have been followed by a crop of brassicas, but these failed and the land at the commencement of the trials in October, 1925, was more or less fallow. Some weeds were present and numerous small potato plants and here and there a seedling cabbage. The principal weeds were:—

Chickweed	(*Stellaria media*)
Groundsel	(*Senecio vulgaris*)
Dandelion	(*Taraxicum officinale*)
Gout Weed	(*Chenopodium album*)
Thistles	(*Sonchus* spp. and *Carduus* spp.)
Couch Grass	(*Agropyrum repens*)
Meadow Grass	(*Poa* spp.)

The soil is mainly silt with abundance of humic matter in the top 6″—8″; and below this depth the silt is hardly relieved at all by the presence of humus and is referred to by the farmers as 'raw silt'. The field is well drained and was fairly dry when the experiments were commenced and though numbers of turfs were examined very few wireworms were found; most of these were located about the roots of the potatoes, dandelions, yarrow, and couch grass. Wet weather ensued in early November followed by hard frosty weather until mid December when a thaw set in. Normally the rainfall in the locality is about 24″ per annum falling chiefly in summer and winter, the springs and autumns tending to be fairly dry.

Wireworm Content.

The field was marked out and sampled, each sample, 6″ square, being examined in three 3″ layers; 82 samples were taken and 81 wireworms found, from this the wireworm content of the field works out at approximately 172,000 wire-

worms per acre. For comparison two normal arable fields which have been ploughed up for some years were sampled in the same way, revealing in each case a wireworm content of below 4,000 per acre. In all cases the wireworms were of the *Agriotes* type, and adults of *A. obscurus* are common in the district.

Trials of Baits for Wireworms

Bait rows, each 10 yards long, were laid down to test the power of attraction for wireworms of germinating seeds, potatoes, and bran and grass. The rows were 5 feet apart and the baits were set at various depths; the bait rows were arranged as indicated in Table I and after fourteen days they were examined and the figures given in Table I were obtained.

TABLE I.

Row No.	Bait	Depth	Wireworms Attracted
1.	Chopped Potatoes	4 " deep	41
2.	Oats	2-3" deep	89
3.	Wheat	2-3" deep	88
4.	Chopped Potatoes	3 " deep	24
5.	Beans	2-3" deep	51
6.	Peas	2-3" deep	33
7.	Potatoes	2 " deep	15
8.	Grass	4 " deep	34
9.	Oats	2-3" deep	32
10.	Wheat	2-3" deep	46
11.	Grass	3 " deep	55
12.	Beans	2-3" deep	41
13.	Peas	2-3" deep	42
14.	Grass	2 " deep	37
15.	Bran	4 " deep	64
16.	Oats	2-3" deep	38
17.	Wheat	2-3" deep	47
18.	Bran	3 " deep	52
19.	Beans	2-3" deep	34
20.	Peas	2-3" deep	62
21.	Bran	2 " deep	47

From Table I it will be seen that the wireworms between every two rows had a choice and it is interesting to note that there are indications that this choice was made for the totals attracted to each bait are given in Table II.

TABLE II.

Bait	Wireworms Attracted
Wheat	181
Bran	163
Oats	159
Peas	137
Beans	126
Grass	126
Potatoes	82

In a second series of trials these baits, omitting grass, were set in duplicate rows six feet apart and twenty yards long and examined in yard samples on the dates shown in Table III. It was thought that the experiment would furnish information on the speed with which the baits act and again give some idea of the preference if any, shown by the wireworms.

The results given in Table III indicate that bran attracted wireworms most speedily but that wheat gradually increased in attractiveness over a longer time. Possibly this was because the bran tended to become mouldy while the wheat germinated and commenced producing rootlets and young succulent plumules. Oats increased in attractiveness very considerably the longer the bait was exposed, but was slow in becoming attractive. From the experiment therefore it is concluded that where only a short time is available for baiting, bran or wheat are most likely to be satisfactory but where there is no pressure on time oats might be used on the score of cheapness and availability on most farms. Peas proved more attractive than beans, and it was found that with beans the wireworms tunnelled into the swollen cotyledons; a habit which might prove disadvantageous for fumigation treatment.

One interesting fact established by these trials with baits, and hitherto not recognized in England, is that germinating seeds exercise considerable attraction to wireworms and this bears out observations made in America and in Russia.

Having compared the attractiveness of these baits it was necessary to determine what distance apart to set the bait rows and for this purpose two small trials were carried out. Beans and wheat were used for this purpose, the former set at distances varying from 2 feet to 6 feet, the latter from 2 feet to 10 feet. The results of this test are given in the accompanying table.

TABLE IV.

Bait	Row No.	Distance Apart	Wire-worms Attracted	Wire-worms in Interspace	Percent Attracted
Beans	1		26		
	2	2 feet	17	3	85%
	3	3 feet	15	4	79%
	4	4 feet	12	6	67%
	5	5 feet	14	18	44%
	6	6 feet	10	21	32%
Wheat	1		11		
	2	2 feet	15	1	94%
	3	3 feet	6	1	86%
	4	4 feet	10	1	91%
	5	5 feet	8	4	67%
	6	6 feet	11	8	58%
	7	7 feet	12	2	86%
	8	8 feet	12	7	63%
	9	9 feet	27	4	87%
	10	10 feet	25	4	86%

Little could be determined from these results but it was concluded to be inadvisable to space rows farther apart than 6 feet and that if they could be spaced at a less interval the efficiency of the bait would be increased. In baiting a field roughly four acres in area it was found that a 'Coultas' corn drill could be set to drill rows 3 feet 3 inches apart and plant 28 to 35 pounds per acre.

TESTS WITH CALCIUM CYANIDE FOR WIREWORM CONTROL.

Method of Application.

Baits were set in rows 6 feet apart and were exposed for fourteen days. The Cyanogas Calcium Cyanide in granular form was applied to bait rows and left undisturbed for about a week before being examined. The material was applied by means of a 'Planet Jr.' hand drill provided with a special opening plow which rendered it possible to deposit material about 4″ deep. Little was known of the possible rates of application with this machine hence a known weight of Cyanogas Calcium Cyanide was applied to bait rows and the length of rows treated measured up. With the setting gauge fixed at 'Salsify' 1 lb. of Cyanogas Calcium Cyanide was applied per 60 yards linear which works out approximately 40 lbs. per acre. Rain had fallen during the night before the Cyanogas was applied and the soil was rather wet.

TABLE III.--ATTRACTIVENESS OF WIREWORM BAITS

Bait	Dates Planted											Total 1st 12 Days	Dates Planted										Total 2nd 12 Days	Total for Period
	October 13	14	15	16	17	19	20	21	22	23	24		October 26	27	28	29	30	31	November 2	3	4	5		
	Wireworms Attracted												Wireworms Attracted											
Bran		4	3	2	6	6	6	10	9	9	11	66	2	5	4	1	2	0	1	0	0	1	16	82
Oats		6	1	1	2	2	3	2	6	6	2	31	19	1	15	11	5	22	14	5	1	2	95	126
Wheat		7	1	0	2	9	7	10	12	6	5	59	3	5	1	2	2	9	8	6	8	11	55	114
Peas		1	2	3	2	1	4	4	12	7	4	40	4	2	2	3	2	7	2	14	3	4	43	83
Beans		4	2	1	1	7	1	1	4	5	3	29	1	0	1	4	0	9	4	6	5	9	39	68
Potatoes		1	0	1	0	1	2	6	16	10	7	44	2	2	0	0	2	4	4	4	3	4	25	69
Bran		4	2	2	12	9	5	17	7	10	3	71	4	0	2	3	3	2	2	0	1	2	19	90
Oats		2	2	1	2	11	4	3	9	8	5	47	4	1	8	8	3	20	8	14	12	17	95	142
Wheat		2	5	4	3	8	5	7	6	15	8	63	14	6	2	7	7	17	12	17	12	8	102	165
Peas		6	1	2	4	2	3	8	13	5	6	50	6	4	7	6	6	2	9	6	4	7	57	107
Beans		2	1	3	6	6	2	13	6	7	5	51	6	3	2	5	5	3	0	4	0	10	38	89
Potatoes		3	3	1	4	6	4	4	5	13	3	46	6	2	6	2	5	8	2	2	1	3	37	83

TABLE V.

Bait	Row No.	Dressed Plot Alive	Dressed Plot Dead	Dressed Plot Total	% Kill	Untreated Plot Alive	Untreated Plot Dead
Peas	1	14	24	38		24	0
	2	16	4	20		24	0
	3	6	10	16		17	0
		36	38	74	51.35%	68	0
Beans	1	10	8	18		16	0
	2	5	18	23		18	0
	3	14	25	39		12	0
		29	51	80	63.75%	46	0
Oats	1	18	4	22		16	0
	2	8	8	16		16	0
	3	25	16	41		48	0
		51	28	79	35.44%	80	0
Wheat	1	22	5	27		20	0
	2	9	5	14		32	0
	3	9	16	25		63	0
		40	26	66	39.39%	115	0

The totals of the whole trial work out at 143 wireworms killed out of 299, or 47.82%.

Influence of Depth of Baiting.

In order to determine the influence of depth of baiting on the killing efficiency, rows of bait were set at depths of 2″, 3″, and 4″. The baits were again exposed for fourteen days before the Cyanogas Calcium Cyanide was applied and rain commenced to fall immediately after the material was applied. The dosage was approximately 40 lbs. per acre.

TABLE VI.

Bait	Treated Alive	Treated Dead	Treated Total	% Kill	Untreated Alive	Untreated Dead	Untreated Total
Bran 2″ deep	34	13	47	27.66			
Bran 3″ deep	25	9	34	26.47	18	0	18
Bran 4″ deep	33	9	42	21.43	22	0	22
Grass 2″ deep	10	12	22	54.54	15	0	15
Grass 3″ deep	5	14	19	72.68	35	1	36
Grass 4″ deep	7	9	16	50.62	18	0	18
Potato 2″ deep	7	3	10	30.00	5	0	5
Potato 3″ deep	5	7	12	50.83	14	0	14
Potato 4″ deep	12	7	19	36.84	22	0	22
Totals	138	83	221		149	1	150

From this test it was concluded that 3″ is the most satisfactory depth at which to set baits when the Cyanogas Calcium Cyanide can be set only at a depth of 4″.

Relation of Time of Exposure of Cyanogas Calcium Cyanide to its Toxicity.

In this test six rows of beans were used and after having been sown fourteen days, the rows were drilled with Cyanogas at the rate of 40 lbs. per acre. The first three rows were examined after six days and the second three after twelve days; the results are found in Table VII.

The difference in the percent kill is so little that, although the numbers are too small to draw any definite conclusions, the indication is that as far as toxicity to wireworms is concerned, Cyanogas Calcium Cyanide is likely to kill the great majority during the first six days after application.

TABLE VII.

Bait	Row	Wireworms			
		Alive	Dead	Total	% Kill
Beans	1	2	8	10	
	2	1	2	3	
	3	1	4	5	
		4	14	18	77.7%
	4	1	1	2	
	5	0	5	5	
	6	2	5	7	
		3	11	14	78.5%

The Influence of the Dosage of Cyanogas Calcium Cyanide per Acre on Toxicity.

Fifty rows, 5 feet apart, each 10 yards long, were drilled with wheat 2″—3″ deep and after fourteen days were treated with Cyanogas Calcium Cyanide at varying weights. The material was applied at a depth of 4″ with the 'Planet Jr.' hand drill. The results are given in Table VIII.

TABLE VIII.

Row No.	Dressing of Cyanogas Per Acre	Dressed Plots	
		Plot 1 % Kill	Plot 2 % Kill
1	34 lbs.	75%	60%
2	39 lbs.	76%	76%
3	45 lbs.	83%	81%
4	51 lbs.	78%	64%
5	56 lbs.	66%	76%
6	62 lbs.	84%	82%
7	68 lbs.	86%	78%
8	73 lbs.	91%	91%
9	79 lbs.	93%	100%
10	85 lbs.	93%	88%
11	90 lbs.	97%	93%
12	96 lbs.	100%	100%
13	102 lbs.	90%	100%
14	107 lbs.	94%	100%
15	113 lbs.	91%	100%
16	119 lbs.	96%	100%
17	124 lbs.	100%	100%
18	130 lbs.	95%	100%
19	136 lbs.	97%	100%
20	143 lbs.	100%	100%

In ten untreated rows which acted as a check 137 wireworms were found and all were alive. In this test over 90% kill was obtained with 73 lbs. per acre of Cyanogas and when the dressings reach 90 lbs. per acre there is no drop below 90% kill. Under conditions at Boston, Lincolnshire, therefore, the indication is that 90 to 100 lbs. of the material per acre used judiciously will give satisfactory control of wireworms.

General Conclusions.

Work in England bears out the fact that Cyanogas Calcium Cyanide is definitely toxic to wireworms and when used in conjunction with suitable systems of prebaiting, is likely to prove an economic method of controlling this pest.

Acknowledgments.

I am indebted to Mr. Frank Waite of Boston for his kindness in placing his field at my disposal for the investigations and to Mr. J. H. Smith, my Technical Assistant, for his great care in recording the experiments.

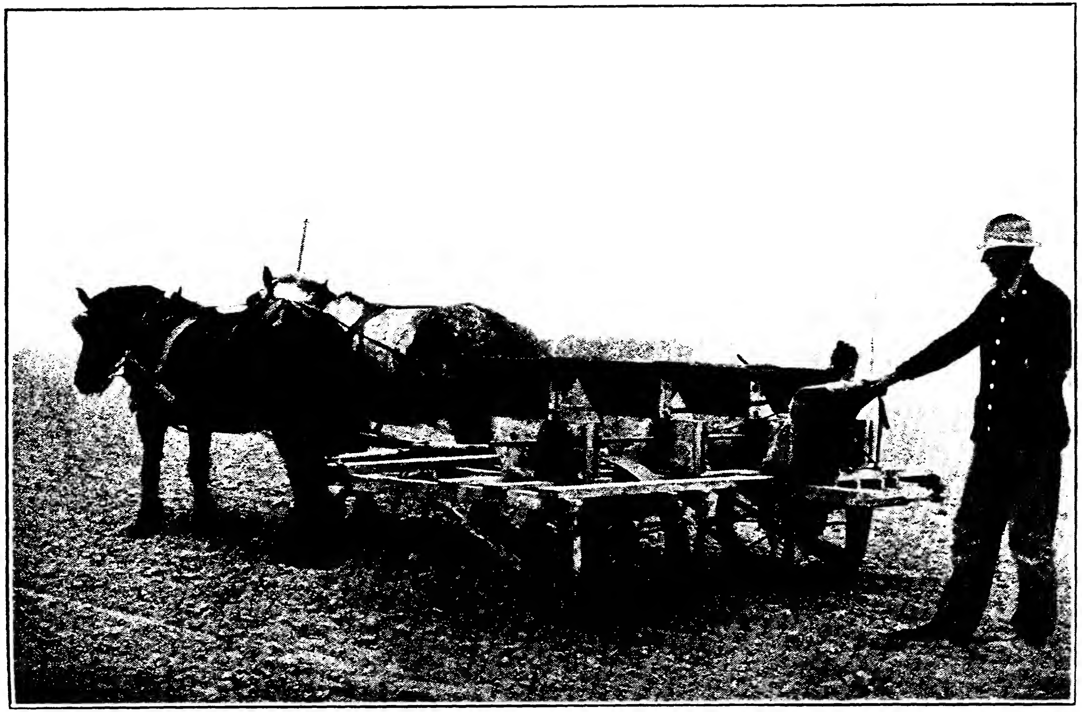

Fig. 2—Ventura Bean Planter Used to Drill Seed Bait and Cyanogas—Azusa, Calif.

METHODS OF APPLICATION

The grower should select the method of application which will fit in most economically with the several factors involved such as; profits to be expected from the crop which follows, the nature of infestation, time of year application is made, and the relative amount of organic matter in soil which might serve as counter-attractant to wireworms. The methods of applying Cyanogas Calcium Cyanide have been designated as:

1—Prebaiting Method
2—Live Bait Method
3—Broadcast Method

PREBAITING METHOD: This procedure is recommended in preference to the other methods which follow. It is economical and is certain to give the desired results. It is, however, dependent upon the forethought of the grower for its success since it must be applied ahead of the season's crop.

The infested field is plowed and disced as early in the spring as possible. A bait of seeds is drilled in continuous rows, two and one half to three feet apart at a depth of two and one half to three inches. Lima beans, Kentucky Wonder beans, split peas, corn, wheat, bran and cotton seed have all been used with success as attractants. This bait should be drilled at a time when wireworms are beginning to show activity in the spring or usually about the time the soil temperature has reached a point where seeds will readily germinate.

Two weeks after the seed has been drilled, the majority of the wireworms will be concentrated in these rows feeding on the bait. This time factor can be checked by making diggings in and between the bait rows (Fig. 1). If these diggings fail to disclose any appreciable number of worms between the rows, it is time to apply the fumigant. The Cyanogas Calcium Cyanide is drilled into the ground along the rows of seed with any seed drill which is used in ordinary farming operations. The amount applied should be about six pounds to each one thousand linear feet. Where the rows are 2½ feet apart the amount of Cyanogas used will approximate one hundred pounds per acre. The Cyanogas should be drilled in to the depth of the seed bait or slightly below it. The material will thus be placed at the level of wireworm concentration.

Although experiments have shown that effective kills of wireworms may be obtained at a distance of three inches from the Cyanogas, the best results have been obtained where the Cyanogas Calcium Cyanide was drilled so that it followed the bait rows closely.

Seven days after the Cyanogas Calcium Cyanide has been applied, the field may be prepared for planting the regular crop.

Experiments have shown that when a field is cleared of wireworms, the crop grown on such a field the succeeding year is free from wireworm damage (Fig. 3). Thus the cost of treatment with Cyanogas Calcium Cyanide may be distributed over a period of three years, since this time would have to elapse before larvae hatching from eggs laid the year after treatment would be large enough to cause serious damage.

LIVE BAIT METHOD: This procedure is very effective and may be used by the grower who has failed to clean up his field before planting his crop and who finds that the infestation is localized in small areas of the field. This method has been so named because the live, growing plants are the bait upon which the wireworms are concentrated. Such crops as corn, beets, sugar beets, cabbage, and tobacco may be cited as examples of crops in which these areas of infestations are often sharply defined.

The treatment with Cyanogas Calcium Cyanide, should be applied when the wireworms have concentrated at the rows. If the crop is growing in continuous rows the Cyanogas should be drilled into the ground at the rate of six pounds to 1000 linear feet as close to the roots of the small plants as possible. Application should be made at the depth of greatest wireworm concentration.

If the crop consists of individual plants in hills such as cabbage, tobacco, or field corn, the wireworms in localized areas may be killed by treating the individual plants. A hole about three inches in depth is made with a sharpened stick close to each plant and about ¼ oz. (six grams) of Cyanogas Calcium Cyanide placed in the hole and covered with earth. The gas will penetrate the soil about the roots of the plant and kill the feeding wireworms. The plants in the treated area may be killed by the Cyanogas Calcium Cyanide but they would probably have been killed by the wireworms or have been so stunted in growth as to be unfit for market.

Fig. 3. Field Treated with Cyanogas, Broadcast Method, 300 Pounds per Acre, Spring of 1924. Photo Spring 1925. No Damage by Wireworms.

Fig. 4.—Untreated Field Adjacent to that Shown in Fig. 3. Wireworm Damage Fifty Percent.

It is possible to prevent injury to nearby uninfested plants by cleaning up these small areas of infestation. If such cleanup is not obtained, the wireworms move along the rows and attack fresh plants after killing those upon which they have been feeding in the original area. It is also possible, by killing wireworms in this manner, to reset or replant such areas and obtain a good stand of plants. If the wireworms have not been killed, the resets will be attacked as severely as were the original plants. Failure to make a cleanup often necessitates replanting several times before a stand can be obtained. In replanting such a crop as corn which is evenly spaced and cultivated in both directions it is necessary to wait one week after treatment of a hill before replanting in order that the gas from the Cyanogas Calcium Cyanide will be entirely dissipated. In the case of crops in rows cultivated in only one direction, such as tobacco or early cabbage, the resets may be planted immediately if plants are set about six inches distant from point of treatment with Cyanogas Calcium Cyanide.

This method of application, while very effective, is recommended only in those cases where the grower has failed to use the Prebaiting Method in early spring before planting the crop.

FIG. 5.—Plow Applicator Used to Apply Cyanogas in Plow Furrow.—Azusa, Calif.

BROADCAST METHOD: This method is best suited for use on those fields where there is a considerable amount of organic matter in the soil which would render a bait crop ineffective. The field to be treated should be plowed as late in spring as possible so that the wireworms will all move above the depth of the plow furrow. A device is attached to the beam of a walking plow which scatters the Cyanogas Granular Calcium Cyanide in the bottom of the furrow ahead of the plow at any desired dosage (Fig. 5).

Where such a device is not available very satisfactory results have been obtained by drilling the Cyanogas into the furrow with a fertilizer drill of the wheel-barrow type or with a seed drill. In any method the Cyanogas should be covered over immediately with soil to prevent loss of the gas. The dosage should approximate 400 pounds per acre.

DESIRABILITY OF METHODS COMPARED

Each of the methods in which Cyanogas Calcium Cyanide may be applied has certain advantages which must be taken into consideration by the grower who plans to use the material. The choice of method is dependent upon the time factor, value of the crop to be grown, and season of the year.

The Prebaiting Method and the Live Bait Method, have the following advantages over the Broadcast Method:

1—Cheaper—30.00 per acre or less, depending upon the spacing of the bait rows and the cost of bait used.

2—More efficient—over a wider range of conditions because the depth and location of the wireworms are definitely known and the Cyanogas Calcium Cyanide can be applied at the same depth or slightly below them.

3—Badly infested spots can be readily located by examination of the trap crop or the live bait, thus eliminating the necessity of treating non-infested portions of the field.

The Broadcast Method has the following advantages:

1—Less time required.

2—Can be used in fields containing large quantities of wireworm food, when it would not be possible to attract the worms to a trap crop.

3—Can be used at seasons when worms are more or less inactive.

FACTORS WHICH INFLUENCE RESULTS

The following factors should be given careful consideration when using Cyanogas Calcium Cyanide for wireworm control in order that maximum results may be obtained.

1. Soil moisture—Enough moisture for usual growing conditions. Dry enough to be easily worked. If soil is too wet, gas does not permeate readily.

2. Condition of soil. For best results soil should be freshly plowed before baits are sown and finely pulverized with disc or drag.

3. Depth of treatment. Cyanogas should be placed at a depth which is equal to or a little lower than the level of wireworm concentration.

4. Distribution. Machine should be used which will give even distribution of the Cyanogas Calcium Cyanide.

5. Cyanogas should be covered with soil immediately to prevent the loss of gas in the air.

6. Season. Spring treatments with gradually rising temperature of soil are somewhat more effective than fall treatment when soil temperature is dropping.

7. Timing of Treatment. In case of prebaiting a period of two weeks should elapse before sowing of bait and treatment with Cyanogas Calcium Cyanide.

A recent paper, discussing the control of wireworms in the Eastern United States by J. L. Horsfall and C. A. Thomas, is reproduced from the Journal of Economic Entomology, Vol. 19, No. 1, February, 1926, p. 181.

A PRELIMINARY REPORT ON THE CONTROL OF WIREWORMS ON TRUCK CROPS[1]

By J. L. Horsfall and C. A. Thomas

Abstract

During recent years, wireworms have caused much damage to truck crops in the Philadelphia area. Preliminary experiments indicate the possibility of controlling these pests successfully with calcium cyanide used as a soil fumigant. The use of a trap bait in the spring followed by an application of granular calcium cyanide before the crops were planted, gave the most promising results. Summer treatments killed many wireworms, but caused injury to cabbage and celery. Fall treatments were only partly successful, due to the depth of the insects in the soil at this time, their decreased activity, and to other factors.

During recent years, wireworms of the genera Phelctes and Agriotes have caused severe injury to beets, carrots, cabbage, celery, parsnips, potatoes and corn in southeastern Pennsylvania, especially in the intensely cultivated area about Philadelphia, where the land has been under constant cultivation for years.

The failure of the usual measures recommended to control these insects on field crops, to check them under truck crop conditions, made it necessary to try out other control methods. Accordingly, in the spring of 1923, tests with granular calcium cyanide as a soil fumigant were made on wireworms feeding on cabbage roots.[2] Since that time further tests were conducted to determine the best method of applying the cyanide, and to find out at what time of the year best control could be obtained. For the latter, treatments were made during early spring before

[1]Published by permission of the Director of the Agricultural Experiment Station as a part of Project No. 698. Contribution from the Department of Zoology and Entomology, The Pennsylvania State College, No. 404.

[2]Journal of Econ. Ent., 17, No. 1, Feb. 1924. p. 160.

the crops were planted, in the summer while they were growing, and in late fall after all crops were harvested.

Spring treatments with calcium cyanide were made as follows:

1. Cyanide drilled into the soil after the planting of baits.
2. Cyanide broadcasted by a lime-spreader, and then plowed under.
3. Cyanide placed in plow furrow by drill, then covered.
4. Cyanide distributed by applicator attached to plow.

1. Cyanide Drilled into the Soil after the Planting of Baits

A field heavily infested with wireworms was disked and planted with sweet corn, 2½ inches deep, in rows 4 feet apart. At the time of planting (April 7), no wireworms were found in the upper seven inches of soil, but by April 25, they were present in the rows feeding on the corn. At this time, granular calcium cyanide was applied to the surface of the soil immediately above each row of corn by means of a wheelbarrow fertilizer drill. A man followed close behind with a small tractor cultivator, and worked the cyanide into the soil to a depth of three inches. Part of the field received 400 pounds per acre, the remainder 200 pounds per acre.

Diggings in the rows one hour after treatment showed a kill of from 70 to 80%, the higher percentage being found in the 400 pound plot. Diggings several days later, however, showed that many wireworms had migrated to the corn from between the rows, even though the odor of cyanide gas was still evident in the rows. This would seem to indicate that the gas did not have much, if any repellent action against the insects. It also shows, as did diggings between the rows after the latter were treated, that the application was made too soon, for many wireworms were found still some distance from the corn. The low soil temperatures which prevailed between the planting of the corn and treatment also slowed up the movement of larvae into the rows. Rows planted 2 feet apart instead of 4 feet would undoubtedly have given better results.

Plowing the soil before it is disked and planted to the trap crop would facilitate the movement of the wireworms to the corn. Small scale experiments on depth treatment of the insects in flower pots likewise show that the use of a drill which would place the cyanide at the level of or below the baits, is a much more effective method of applying the material, and reduces the amount of cyanide required.

Carrots planted later on the plots described above, showed at harvest time 2.84 per cent injury in the plot receiving 400 pounds of cyanide, and slightly more than 4 per cent injury in the plot receiving 200 pounds.

2. Cyanide Broadcasted by a Lime-spreader and then Plowed Under

In April, 1925, a one acre field was divided into four equal plots, and granular calcium cyanide was drilled upon the surface of each by a horse-drawn lime-spreader having a width of 8 feet, and with holes 8 inches apart in the bottom of the hopper. The field was then plowed 8 inches deep with a double plow drawn by a tractor. At the time of treatment wireworms were abundant in the field, about 85% of them being in the top four inches of soil. This treatment gave a kill of over 70 per cent in all plots, with the greater kill in the plots receiving the heavier dosages.

Two weeks after treatment, carrots and parsnips were planted in all four plots. The following table shows the results of treatments, the dosage given each plot, and the number of days the cyanide gas remained in the soil after treatment.

Plot No.	Lbs. of $Ca(CN)_2$ used	Last positive CN test	No. ft. of row examined	No. of carrots examined	% of carrots injured by wireworms	% of parsnips injured by wireworms
1	75	3 days	585	1730	4.39	0
2	112	5 "	612	2088	3.51	0
3	150	12 "	600	2105	3.28	0
4	250	12 "	600	2093	5.70	0

The check on these plots was a field several hundred feet distant from the above treated plots. This field which showed approximately the same number of wireworms as the treated plots, later showed about 12 per cent injury to the carrots.

This table shows that cyanide treatments considerably reduced the amount of damage. The greater per cent of injury in the 4th plot was found to be due to the migration of wireworms into it from an adjacent untreated plot. The inside rows of this plot showed approximately 2.5 per cent injury

None of the growing parsnips were damaged by the wireworms. The seed is often eaten by them after planting, but in these plots the absence of injury was due to the killing effects of the treatments. By the time any wireworms had moved into the treated plots, the plants had reached a stage when they were apparently not attractive to them.

3. Cyanide Placed in Plow Furrow by Drill, then Covered

In this field, furrows 14 inches wide and 5 inches deep were plowed, and granular calcium cyanide at the rate of 300 pounds per acre was placed in the furrows with a wheelbarrow fertilizer drill. The cyanide

was covered at the next round of the plow. Maine Cobbler potatoes were planted ten days later. An adjoining untreated half acre was used as a check.

Counts and weighings of potatoes at digging time showed 17.2 per cent injury by wireworms on the treated field, and 37.3 per cent injury on the check. The amount of injury in the treated plot indicates that either the dosage was not heavy enough, or that the rows of cyanide were drilled too far apart. The plants on the treated field were greener and larger, indicating that the cyanide has some stimulating effect. Yields from these fields were as follows: treated field—308 bu. per acre: check 241.6 bu. per acre.

In the spring of 1925 these two fields were drilled with the same kind of beet seed at the same time. Examination during the summer showed an excellent stand of beets in the field treated last year, only five plants in the whole field dying from wireworm attack. In the adjacent field which had received no previous treatment, wireworms destroyed over 50 per cent of the stand. This would seem to indicate that the 1924 treatment so cleared up the infestation in the treated field, that there was but slight injury during 1925.

4. Cyanide Distributed by Applicator Attached to Plow

In 1924, a plot infested with wireworms was treated with calcium cyanide by means of an applicator loaned by the American Cyanamid Company. This was attached to the plow in such a manner that the cyanide was dropped just ahead of the plow blade, and was turned under at the next round of the plow. 225 pounds of cyanide per acre were applied. Double plows digging a furrow 5 inches deep, and placing the cyanide in rows 28 inches apart, were used in this experiment.

The field was planted to carrots ten days after treatment. Counts in August showed that wireworms had injured 17 per cent of the crop. The use of the applicator on a single plow would have placed the rows of cyanide closer together, and probably would have given better results.

It is interesting to note that only 5 plants out of a total of 5000 planted in this field the year following treatment were killed by wireworms.

Treatments with calcium cyanide have also been tried in summer during the growing season against wireworms attacking the roots of cabbage, and the roots and crowns of celery. The cyanide was applied around the base of cabbage plants in several different ways, and although it killed many of the insects, it also killed the plants. Summer applications for wireworms on cabbage, therefore, cannot be recommended.

though they would be of value in cleaning up a badly infested area, and thus preventing spread to uninfested portions of a field.

In the case of celery, two different methods were tried. In one series of experiments varying doses of cyanide were placed in furrows close to the plants and covered with soil. Examinations showed that a large percentage of the wireworms feeding on the outside of the roots were killed, but that dosages strong enough to kill them in the crown of the plants, were also fatal to the plants. In the second series of experiments, corn was drilled between the celery as a bait crop at various distances from the plants. Subsequent diggings showed that the corn failed to serve as a lure, the insects remaining on the roots and crowns of the celery.

In November, 1925, small plot experiments were tried in which the cyanide was placed in holes 6 to 8 inches deep, in soil containing larvae and adults of *Pheletes agonus* Say, the common destructive wireworm in the Philadelphia area. This is the depth usually attained by fall plowing. Only fair success resulted from these experiments for which the following reasons may be given: in late October the larvae of this species are moving down in the soil; by mid-November, a large number of them are below the plow line, and beyond the influence of calcium cyanide placed at that depth, especially if the soil and subsoil contain a high percentage of moisture at the time of treatment; the larvae are less active at this time, and seem to succumb less readily to the gas; many of the adults are also below the plow line, and are not attracted by baits at this time of the year. It would thus seem that fall treatments for these insects are not practical.

Summary

Calcium cyanide is the best soil fumigant found thus far for the control of wireworms on truck crops.

Spring treatments have given the best control of these pests.

Of these spring treatments, drilling in the cyanide after the insects have reached a previously-planted bait crop, has been most effective.

Summer treatments of cabbage and celery are not recommended because of toxicity to such plants.

Fall treatments, up to the present, have not proved practical.

THE CONCENTRATION OF WIREWORMS BY BAITS BEFORE SOIL FUMIGATION WITH CALCIUM CYANIDE

By Roy E. Campbell, *Bureau of Entomology, U. S. Dept. of Agriculture*[1]

Abstract

Applications of 200 to 300 pounds of granular calcium cyanide to the acre with a grain drill under certain conditions will kill a high percentage of the wireworms in the soil, but ordinarily this treatment is too expensive for commercial use. Therefore, advantage was taken of the fact that wireworms will collect in rows or hills of seeds, and several kinds of seeds were planted as baits to concentrate the wireworms in rows. By this method a fairly heavy dosage can be applied to the baited rows, and the amount required to the acre will be considerably less than in broadcast treatment. Beans, peas, and corn all proved satisfactory attractants and concentrated a large percentage of the wireworms in the rows. The effectiveness of the baits was reduced if other foods, such as the remains of an old crop, were left in the field. Experiments showed that the most satisfactory amount of calcium cyanide, considering both the lethal effect and the cost, was 5 to 5.5 pounds per 1,000 feet of row. For baited rows 2½ feet apart this will amount to a little less than 100 pounds per acre, and for rows of greater or less width, the quantity will be decreased or increased accordingly. The percentage of wireworms attracted to the baits decreased as the width of the rows increased, being 96 per cent for 2-foot rows and 80 per cent for 4-foot rows. Commercial applications by several growers gave satisfactory results.

In a preliminary report on the use of calcium cyanide as a soil fumigant for wireworms,[2] it was shown that this material is decidedly toxic to these insects. Three hundred and fifty pounds or more per acre applied with a grain drill killed 100 per cent of the worms, while 180 to 200 pounds per acre killed, on an average, 73 per cent, and under favorable conditions as high as 100 per cent.

At the time this report was made, some of the experiments at Toppenish, Wash., were still in progress. In one series an attempt was made to find out the effect of handling the soil, both prior to and subsequent to the cyanide application. Certain plots were plowed 7 inches deep and then treated with different amounts of cyanide. Some of the plots were gone over with a culti-packer immediately after the cyanide was applied, and others were left undisturbed after the treatment. Still other plots were double disked 4 inches deep and given the same applications and treatments as the plowed plots. The results are shown in Table 1.

The results of the experiments reported in Table 1, in so far as the percentage of wireworms killed was concerned, were unsatisfactory. This may be attributed largely to the fact that the experiments were

[1]Mr. John N. Stone assisted the writer in the field work reported herein.

[2]Preliminary report on the use of calcium cyanide as a soil fumigant for wireworms. Jour. Econ. Ent. Vol. 17, Oct. 1924, pp. 562–567.

TABLE 1.—COMPARISON OF THE RESULTS OF CALCIUM CYANIDE APPLICATIONS ON PLOTS PLOWED AND DISKED PRIOR TO TREATMENT AND PLOTS PACKED AND LEFT UNPACKED AFTER TREATMENT. MATERIAL APPLIED WITH A GRAIN DRILL TO A DEPTH OF ABOUT 4 INCHES

Plot No.	Treatment of land before application	Treatment of land after application	Calcium cyanide, pounds per acre	Total number worms counted in plot	Worms dead, per cent	Number potatoes in ten hills	Potatoes damaged, per cent	Potatoes damaged in checks, per cent	Increase by treatment, per cent per acre	Value of increase over cost of material per acre[1]
3	plowed 7″	packed	176	22	77.3	68	16.17	25.8	9.63	—$19.76
15	plowed 7″	not packed	176	26	73.1	44	17.39	34.8	17.41	—9.09
9	dbl. disked 4″	packed	174	29	48.3	59	7.02	21.2	14.18	—12.53
21	dbl. disked 4″	not packed	170	28	39.3	47	29.78	34.8	5.02	—25.50
1	plowed 7″		238	18	83.3	48	10.40	24.1	13.7	—37.05
13	plowed 7″	not packed	238	21	71.4	74	10.50	29.1	18.6	—19.70
7	dbl. disked 4″		238	36	47.2	56	19.60	24.1	4.5	—41.60
19	dbl. disked 4″	not packed	236	23	39.1	49	18.37	29.1	10.73	—30.11
5	plowed 7″		287	20	70.0	63	7.93	22.3	14.37	—36.85
17	plowed 7″	not packed	287	18	77.7	59	7.27	38.5	31.23	—9.96
11	dbl. disked 4″		284	35	45.7	46	1.81	22.3	20.4	—26.80
23	dbl. disked 4″	not packed	281	36	44.4	58	31.00	40.3	9.3	—42.35

[1]Based on an average field production of 200 sacks of 100 pounds each to the acre and selling for $0.75 per sack. Calcium cyanide at 20 cents per pound.

Owing to the variation in the costs of baits, this item is not included in the data given in Table 1 or in subsequent tables. The cost of baiting, including the bait and its application, would vary from 80 cents to $4.25 per acre, depending largely upon the type of bait used. The cost of planting the baits ranged from 50 to 75 cents per acre. In the experiments reported here, from 50 to 75 pounds of bait per acre were used in rows planted 2½ feet apart. This is approximately the same amount as seed used in planting the crop. Refuse or split beans, corn, kafir, beans, or field peas may be used for baits. The price of these materials ranges from 1 to 5 cents per pound. For baits it is not necessary to use high priced seed, but low priced materials such as would do for feed, are satisfactory.

made in June when the wireworms were beginning to go deeper into the soil, and so were not reached by the cyanide as applied with a grain drill to a depth of 4 inches. A large majority of the live wireworms were below the cyanide.

The experiments show, however, that the plots plowed 7 inches deep just prior to the cyanide application all produced better results than those double-disked 4 inches deep. The plowing, going 3 inches deeper than the disking, turned up more worms, which remained in the moist soil near the surface and were exposed to the cyanide fumes. Also, with one exception, the plots which were packed immediately after the cyanide applications showed better results than those which were not packed, although the difference was not great.

In each plot 10 hills of potatoes were dug at harvest time, and the number of potatoes damaged by wireworm feeding or "stings" counted and compared with a check on two sides of each plot. The percentage of wireworms killed was low, ranging from a minimum of 39.12 to a maximum of 83, which was not sufficient to show much benefit from the treatment. The percentage of undamaged potatoes in the plots varied from 4.5 to 30.8 more than in the check, but in no case did the value of the increase equal the cost of treatment.

Results of these experiments compared with those of others indicate that the disk grain drill did not apply the cyanide to a depth great enough to reach the majority of the worms. Another factor which affected the efficiency of cyanide was the temperature of the soil, which on rising, accompanied by loss of moisture, caused the worms to go deeper into the soil.

These experiments as well as previous ones demonstrate that an application of calcium cyanide to the soil will kill wireworms, but owing to the large amounts required when it is sown broadcast in fields, the expense involved is too great for its general use. If the treatment of wireworms with calcium cyanide is to prove practicable, a means of reducing the amount to be used must be discovered.

It is a well-known fact that wireworms will collect in rows or hills of seed crops. It was believed that advantage could be taken of this habit in control by soil fumigation, to concentrate them in restricted areas through the use of baits, and then treat these areas with calcium cyanide. By this method less material per acre would be required than when the calcium cyanide is sown broadcast. Accordingly, a series of experiments was conducted in which corn, peas, and Kentucky Wonder beans were used for baits. A heavily infested field which had previously

been planted to beets was selected. It ultimately proved that this was an unfortunate selection, for it was observed that the beets left in the field acted as counter-baits and reduced the efficiency of the planted baits. In the initial experiments the baits were planted in rows 6 feet apart, but subsequent experiments showed that a lesser distance would have increased their effectiveness. The efficiency of the baits is shown in Table 2:

TABLE 2.—EFFECTIVENESS OF DIFFERENT BAITS PLANTED IN ROWS 6 FEET APART, USED TO ATTRACT WIREWORMS PRIOR TO TREATMENT WITH CALCIUM CYANIDE

Bait used	Per cent of effectiveness[1]	Number of experiments	Number of worms counted
Beans	88	4	183
Peas	74	7	260
Corn	67	7	335

[1]The figures in this column were arrived at by comparing the number of worms per square foot in the rows and the number per square foot between the rows.

The baits were planted on May 27 and treated with various amounts of calcium cyanide on June 28. A hand drill which placed the material about 3 inches deep was used both for planting and applying the seed bait and calcium cyanide. Wireworm counts were made on July 1, and on October 2 ten hills of potatoes were dug in each plot and check plot.

Table 3 shows the results of applications of various quantities of calcium cyanide, after the worms had been attracted to baits, giving the number and percentage of worms killed, the effectiveness of the baits, the percentage of injured potatoes in the plots as compared with those in the checks, and the gain or loss as compared with the cost of the cyanide.

That the hand drill did not place the baits and cyanide deep enough was indicated by the fact that practically all of the live worms in the rows were below the cyanide. An inch or two deeper would have greatly increased the kill, since the worms are mostly from 4 to 6 inches deep at this time of year. The increase in uninjured potatoes over the check plots varied from 2.7 per cent for the lightest application to 35.8 per cent for the heaviest, and averaged 18.4 per cent for all the plots.

Considering the low efficiency of the baits, caused by the presence of the refuse beets in the field, the increase in undamaged potatoes is considered quite satisfactory, four of the plots showing good profits even under the adverse conditions of the experiment.

EXPERIMENTS IN SOUTHERN CALIFORNIA IN 1925

Encouraged by the results obtained in the State of Washington in 1924, further experiments of a similar nature were made in southern

TABLE 3.—EFFECTIVENESS OF BAITS USED, EFFECTIVENESS OF THE DIFFERENT STRENGTHS OF CALCIUM CYANIDE, INCREASE IN NUMBER OF UNINJURED POTATOES, AND THEIR VALUE IN RELATION TO THE COST OF THE CYANIDE TREATMENT. ROWS 6 FT. APART, APPLICATION MADE WITH A HAND DRILL 3 INCHES DEEP

			Wireworms			Potatoes				
Plot No.	Lbs. per acre	Effectiveness of bait, per cent	Total number	Killed in row, per cent	Total killed, per cent	Number dug in 10 hills	Per cent uninjured	Per cent uninjured in check[1]	Increase by treatment, per cent	Value of treatment per acre compared with cost of material[2]
H-7	27	91.3	57	85.4	82.0	43	72.0	69.3	2:7	—$1.55
H-1	47	61.0	55	87.7	78.7	46	65.3	61.8	3.5	—3.75
H-2	77	65.6	106	91.6	83.0	51	84.0	61.9	22.1	+17.75
H-4	95	84.6	192	94.0	90.6	57	52.6	34.7	17.9	+7.85
H-3	118	75.3	196	93.4	87.2	58	69.0	37.3	31.7	+23.95
H-6	147	64.0	71	88.5	76.0	70	80.0	65.1	14.9	—7.05
H-5	165	85.0	97	95.6	92.0	44	75.0	39.2	35.8	+20.70

[1]Checks and plots alternated in this experiment. Each plot is compared to the average of the two checks adjoining.

[2]Based on an average production of 200 sacks of 100 pounds each per acre at $0.75 per sack, and calcium cyanide at $0.20 per pound.

TABLE 4.—COMPARATIVE EFFICIENCY OF DIFFERENT BAITS FOR WIREWORMS, AND ALSO THE EFFICIENCY OF THESE BAITS WHEN PLANTED IN ROWS OF DIFFERENT WIDTHS

Bait	Number of wireworms per sq. ft. in rows of following widths[1]				Number of wireworms per sq. ft. between rows of following widths				Per cent[2] of wireworms in rows of following widths				Total number of wireworms counted in rows of following widths				Total number of sq. ft. from which counts were made, widths of rows			
	2′	2.5′	4′	5′	2′	2.5′	4′	5′	2′	2.5′	4′	5′	2′	2.5′	4′	5′	2′	2.5′	4′	5′
Lima beans[3]	0.70	1.5	2.6	3.2	0.00	0.06	0.09	0.07	100.0	86.2	80.5	83.5	26	92	119	128	66	96	90	100
Corn	0.60	2.5	1.7	2.8	0.0	0.05	.13	0.20	100.0	92.6	65.1	60.9	12	60	27	30	40	40	30	20
Peas	0.60	1.9	1.9		0.02	0.0	0.05		90.9	100.0	84.4		25	74	29		80	80	32	
Misc. Mix.		1.9		3.2		0.05		0.20		90.5		64.0		180		33		154		10
Average	0.63	1.9	2.1	3.1	0.01	0.04	0.09	0.16	95.4	91.8	77.7	68.3					186	370	152	130

[1]In the row the square foot was an area 6″ x 24.″

[2]Since the unit area was 24 inches in length and 6 inches in width, the area between rows was taken from center to center of the area between rows and 24 inches long. These percentages then were based on the calculated number of wireworms in this area.

[3]In these experiments both whole beans and "splits" were used.

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California in 1925, where conditions were somewhat different. Beans, corn, peas, and a miscellaneous mixture were used as baits and planted in rows 2, 2.5, 4, and 5 feet apart. This work was all done on land which had been kept free of plant growth during the winter. The experiments were begun in April soon after the worms became active. The effectiveness of the baits is shown in Table 4.

There appeared to be little difference in the attractiveness of the several baits used, but the experiments indicate that as the distance between the rows increases the percentage of wireworms attracted to the baits decreases.

Since crops are planted in rows of different widths, the rate of application per acre will necessarily be considered with regard to the width of the row. The following table gives the variation in the rate per acre of various amounts per 1,000 feet of row, for rows of different widths.

TABLE 5.—RATE PER ACRE FOR CERTAIN AMOUNTS OF CALCIUM CYANIDE PER 1,000 LINEAR FEET OF ROW, FOR ROWS OF DIFFERENT WIDTHS.

Lbs. per 1,000 ft. of row	Distance apart of rows 2′	2.5′	3′	4′	5′
	Pounds per acre				
4.5	98.2	78.6	65.4	49.1	39.3
4.8	104.8	83.8	69.8	52.4	41.9
5.0	109.2	87.3	72.7	54.6	43.6
5.5	120.1	96.0	80.0	60.0	58.0
6.0	131.0	104.8	87.2	65.5	52.4
6.3	137.5	110.0	92.6	68.7	55.0
7.0	152.8	122.3	101.8	76.4	61.1
7.7	168.1	134.5	112.0	84.0	67.2

A number of experiments were made early in the season of 1925 to determine both the attractiveness of the bait and the effect of the cyanide. Results of the tests have been included in Table 6, which shows the results of different strengths of cyanide applied in rows where trap crops had previously been planted.

TABLE 6.—EFFECTIVENESS OF DIFFERENT AMOUNTS OF CALCIUM CYANIDE APPLIED IN ROWS OF DIFFERENT WIDTHS AFTER THE WIREWORMS HAD BEEN CONCENTRATED BY BAITS

Lbs. per 1,000 ft. of row	Per cent of worms killed Max.	Min.	Avg.	No. of experiments	Number worms counted to get per cent of kill
4.5	100	60	83.99	14	235
4.8	90	80	86.5	9	203
5.25	100	87.5	90.8	5	66
5.5	100	70	90.8	24	434
6.3	96.43	95.23	95.8	2	70
7.7	100	100	100.0	1	28

The data obtained indicate that as the dosage increases the mortality increases. It also indicates that an average kill of practically 91 per cent was obtained by using from 5.25 to 5.5 pounds per 1,000 feet of row. By reference to Table 5 it appears that this rate is approximately 90 to 100 pounds per acre for 2.5 ft. rows. This amount is suggested as the best for general purposes. The cost is about $20.00 per acre for rows 2.5 feet apart, and less or more according as rows of less or greater width are used.

On hearing of the results obtained in these experiments, several bean growers decided to make commercial treatments of an acre or more on their infested lands. In some fields split beans were drilled in for baits, while in others the lima beans which had been planted for a crop became so badly infested that these were treated. The cyanide was drilled in with the Ventura type 4-row bean planter, all rows being 2½ feet apart. All of the work was done by the growers themselves, under general directions. From 10 to 20 feet of row were examined in several parts of each field, and the number of dead and live worms counted. In most fields examinations made between the rows showed the baits about 90 per cent effective, and in several fields practically 100 per cent effective. In tests where two applications of 45 and 70 pounds of cyanide per acre were made, an average kill of 50 per cent resulted. Where 7 applications of from 90 to 110 pounds per acre were made, the kill varied from 79 to 100 per cent, while one application at 145 pounds per acre resulted in a kill of 100 per cent.

In all of the experiments reported in this paper, granular calcium cyanide was used. This is a crude cyanide ground to the fineness of coarse coffee, and with a cyanide content equivalent to from 40 to 50 per cent of sodium cyanide. Laboratory and field experiments were performed with a dust form of calcium cyanide, which had a sodium cyanide equivalent of from 25 to 35 per cent. This gave poorer results, and, moreover, in the fine dust form, was both more unpleasant and difficult to handle than the granular form.

Issued October 25, 1926.

SECTION 6

DUSTING—OPEN AIR

Dusting—Open Air

In 1922, Professor W. P. Flint, State Entomologist of Illinois, tried out a series of dusts consisting of powdered Cyanogas Calcium Cyanide mixed with ground spent tobacco dust. These dusts were blown over chinch bugs infesting grass and corn stalks. An account of this work is given on page 7-2 and is the earliest published reference to the use of Calcium Cyanide for open-air dusting.

Fig. 1-6.—Dusting for Grape Leafhopper, Imperial Valley, California. Application with Hand Duster to Tree Grapes.

GRAPE LEAFHOPPER

Early in 1923, Mr. H. Knight and Mr. F. C. Greer experimented with a mixture of pulverized Cyanogas Calcium Cyanide and hydrated lime for control of the Grape Leafhopper, *Erythroneura comes* Say, in California (Fig. 1-6). The account of this work was published in the Report of the College of Agriculture and Agricultural Experiment Station, University of California, 1922-23, p. 100.

Grape Leaf Hopper Control with Calcium Cyanid Dust.—Grape vines at Oasis, Coachella Valley, were dusted by H. Knight and F. C. Greer with pulverized calcium cyanid and hydrated lime with proportions of 10, 25, 50, and 100 per cent cyanid. Dust when used in strength above 10 per cent destroyed all nymphs and a large proportion of adults. No injurious effects to the vines have been observed. Operations were confined to the Coachella Valley on account of favorable climatic conditions for the use of the dust.

Fig. 2-6.—Dusting for Grape Leafhopper on Trellis Grapes in California with Cyanogas "A" Dust.

Fig. 3-6.—Dusting for Grape Leafhopper in California with Traction Duster.

The first work on the Grape Leafhopper in the Eastern United States was carried out by Professor F. G. Mundinger, working in the Hudson Valley. In his experiments, a dust was used, known as Calcium Cyanide "C" Dust, containing 75% talc as a diluent. His paper dealing with this work and other experiments with Cyanogas Calcium Cyanide Dust was published in the Proceedings of the 69th Annual Meeting, New York State Horticultural Society, 1924, pp. 134-138.

EXPERIMENTS WITH CALCIUM CYANIDE AS AN INSECTICIDE

by F. G. MUNDINGER*

The popularity of dust applications in commercial orchards agains pests that are susceptible to dust treatments has awakened in growers and manufacturers alike a desire to broaden the field of usefulness of dust treatments by the development of new and more satisfactory dusting materials. Calcium cyanide is a material which has recently been developed as an insecticide, and the writer spent the summer of 1922 investigating** the insecticidal value of this material in the fruit districts of the Hudson valley. The cyanide used in the dust form consisted of 25 per cent calcium cyanide with 75 per cent ground talc as a carrier. The killing power of the calcium cyanide is due to the deadly hydrocyanic acid gas which is liberated when this dust is exposed to the atmosphere or when it comes in contact with moisture.

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* Edited by F. H. Lathrop

** This work was done under the fellowship provided by the American Cyanamid Company.

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Tests conducted include the treatment of pear psylla and grape leafhopper with the cyanide dust, while the granular cyanide was tried out as a soil fumigant in controlling the pear thrips, pear midge, and apple maggot.

DUSTING EXPERIMENTS AGAINST PEAR PSYLLA

A number of experiments were conducted in the orchards of Mr. Peter Finger at Germantown, N. Y. An ordinary hand duster was used, and single trees were treated. Applications were made at intervals from June 14 to September 1. The applications were made during the warm portions of bright days with the temperatures ranging from 70 to 92 degrees. An average of about one pound of the dust was used per tree, and it was found that from 2,000 to 20,000 psylla per tree were killed, depending upon the degree of infestation. The per cent of recovery of the psylla that dropped from the tree after the application of the dust was small. No injury to the pear trees could be detected as a result of the treatment.

DUSTING FOR GRAPE LEAFHOPPER

A series of experiments with the use of cyande dust for the control of the grape leafhopper was conducted in the vineyard of Lockwood Brothers, Milton, N. Y., August 3 to 10. The applications were made during the warm portions of the days, and the temperature ranged from 80 to 90 degrees. The vines were dusted from one side by means of a hand duster, care being taken to secure a thorough application.

The season was too far advanced for the best commercial control of the pest, but the results indicate the effectiveness of the material in destroying the various stages of the leafhopper. The results were obtained by counting the number of nymphs and adults present on the treated vines twenty-four hours after the application and comparing this with a similar count made on untreated vines.

The results are summarized in the following table:

TABLE ONE

Results of Dust Treatments against Grape Leafhopper

Date	Treatment	% of nymphs killed	% of adults killed
	Test Number 1		
August 3	Cyanide dust	46	73
	Cyanide dust (vines shaken after application)	29	37
	Untreated vines	0	0
	Test Number 2		
August 3	Cyanide dust	32	21
	Cyanide dust 3 parts		
	Nicotine dust 1 part	54	37
	Untreated vines	0	0
	Test Number 3		
August 6	Cyanide dust	60	37
	Nicotine dust	57	55
	Untreated vines	0	0
	Test Number 4		
August 9	Cyanide dust	63	88
	Cyanide dust	72	90
	Untreated vines	0	0

A study of the above table shows that, on the whole, dust applications failed to give satisfactory control of the leafhopper. In the tests where the two dusts were directly compared cyanide dust and nicotine dust were about equally effective. The highest percentage of kill was obtained with cyanide dust in Test Number 4.

Grape foliage is susceptible to injury from the cyanide dust. In one test burning resulted to several leaves which had accidently received too heavy a coating. In another instance severe burning resulted to a number of leaves on a vine which was dusted several hours before a rain storm.

THE PEAR THRIPS

In the work with calcium cyanide against the pear thrips the pure granular cyanide was used. The object was to use this material as a soil fumigant in an attempt to destroy the larval stage of the insect, which is located in the upper few inches of soil beneath the infested trees.

These experiments were conducted in an orchard on the Peter Fingar farm near Germantown, N. Y. This orchard was heavily infested with pear thrips, and practically every tree in the plat showed signs of serious thrips injury.

The first application of cyanide was to twenty-seven trees on May 25. The temperature at this time was about 78 degrees F. The granular calcium cyanide was sprinkled on the ground beneath the trees at the rate of from ¼ to 3 pounds per tree. This material was then worked an inch or more into the graund by means of a garden rake.

Other applications were made under various conditions of temperature and soil moisture, and the materials were worked into the soil to various depths. In all twenty-four applications were made during the period between May 25 and August 14.

In checking the results of these experiments several samples of soil were taken from beneath the treated trees and, after being pulverized, was carefully sifted onto a slab of black slate. In this way the thrip larvae were collected, and the effect which the treatment had upon them could be determined. Comparisons were made with soil taken from beneath trees which had received no treatment.

Because of the difficulties involved in finding the larvae in the soil, it was impossible to form conclusions upon which definite recommendations could be based. However, in the majority of cases the treatments seemed to be effective, and cyanide offers promise as a soil fumigant for the control of pear thrips. Additional data will be secured next spring when the emergence of thrips under the trees can be noted.

THE APPLE MAGGOT

In the course of the life history of the apple maggot a portion of the time is spent as immature stages in the upper layer of the soil beneath infested trees. This fact suggests the possibility of control by the use of a soil fumigant. Accordingly, a series of tests was applied, using the granular calcium cyanide in a manner similar to that described for pear thrips. Applications were made on August 16 and 27. On August 30 the soil was sifted just as was done in the pear thrips experiments.

The results are not definitely conclusive, but the indications are that the larvae of the apple maggot are killed in the soil by the cyanide fumes. The pupae are more resistant, and further investigation will be

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necessary to determine whether the treatment will be effective against the pupal stage.

THE DEGREE OF DANGER TO MAN IN THE USE OF CALCIUM CYANIDE

Calcium cyanide is a deadly poison, and the fumes which it gives off are even more deadly than the calcium cyanide itself. Naturally, therefore, the question arises as to the precautions which must be taken in the use of this material. It has been found in these experiments that this material can be used for field dusting without injury to the operators, where due precaution is taken to keep out of the dust cloud, and not to inhale the fumes. It would not be advisable to work with this material in tightly closed rooms. Care should be used to avoid getting the material into the mouth or eyes, or into cuts or scratches. This material should, of course, be kept away from children and domestic animals.

CONCLUSIONS

Calcium cyanide holds considerable promise as a dust insecticide.

The 25 per cent cyanide dust seems equally as effective as 2 per cent nicotine dust for the control of pear psylla and grape leafhopper.

When properly applied no injury was observed to result from 25 per cent cyanide dust on pear or grape foliage.

If applied in excessive amounts or while the leaves are wet, or where rain follows soon after application, injury is likely to result.

As a soil fumigant the granular calcium cyanide shows promise for the control of such insects as pear thrips and apple maggot. However, additional investigation is necessary to establish fully its possibilities in this respect.

In 1924, further work was carried out for control of the Grape Leafhopper by Professor H. J. Quayle and was published in the Journal of Economic Entomology, Vol. 17, No. 6, Dec. 1924, p. 668. In the same year, Dr. J. R. Eyer carried out experiments in Pennsylvania, publishing a note in the Journal of Economic Entomology, Vol. 18, No. 1, Feb., 1925, p. 235. These two articles are here reproduced.

Cyanogas Calcium Cyanide "A" Dust is now the standard material used for the control of the Grape Leafhopper in California (Fig. 3-6).

Calcium Cyanide Dust for Control of the Grape Leaf Hopper. Calcium Cyanide dust was used in an experimental way against the Grape Leaf Hopper, *Typhlocyba comes* Say, by this Station in 1923 and again in 1924. From the previous work on this insect it appeared to the writer that if some effective method could be used against the over-wintering adult hoppers soon after they came onto the vine in the spring, that it would be the most desirable way to control the hoppers, but the adults showed great resistance to sprays or dusts heretofore used. The adult hoppers, on the other hand, proved to be susceptible to HCN gas. When the Calcium Cyanide dust is blown into the vine the hoppers are quickly overcome and fall to the ground. If there are no Cyanide particles on the ground the hoppers overcome by the gas will recover, but if there is a slight deposit of the cyanide on the ground sufficient gas will be given off to prevent the recovery.

On short pruned vines the method has been to use a knapsack duster by means of which the dust is shot into the vines from below and the heavier particles drop to the ground. Since the shoots of the vine at this season are only six to ten inches long, there is not much foliage to cover and a small amount of dust will do the work. Later in the season, when the second generation hoppers occur, Cyanide dust will also kill them, although a much greater quantity must be used. It is proposed to carry on work on a larger scale during the coming year, when more definite data will be secured as to the feasibility of controlling the Grape Leaf Hopper by Calcium Cyanide dust.

H. J. Quayle, *Citrus Experiment Station, Riverside, California*

Preliminary Note on the Control of Grape Leaf Hopper with Calcium Cyanide Dust. During the season of 1924 experiments were conducted by the Pa. Bureau of Plant Industry at the Field Station, North East, Pa., to test the value of calcium cyanide dust as a control for the Grape Leaf Hopper in commercial vineyards. Both calcium cyanide "A" and "B" dusts were tested and the material was applied either with a hand or power duster. The "B" dust was applied at the rate of 40 lb. to the acre and the "A" dust at the rate of 25 lb. per acre. In the case of the "B" dust both sides of the row were dusted while with the "A" dust only the windward side received the dust. The dusting was done at the regularly recommended period for the application of the leaf hopper spray in Pennsylvania, i. e. when the majority of the first generation nymphs were in the fourth instar and before an appreciable number of second generation adults had appeared. At this time it was possible to observe the effect of the dust on both the adults and nymphs. The temperature when the dust was applied varied from 70 to 75 degrees F., and the relative humidity from 60 to 80 percent.

In addition to the customary counts of adults and nymphs before and after dusting, collections were made by placing canvas beneath dusted vines and observations were made for 30 minutes after dusting. An exceedingly high percentage of adults and nymphs were killed by both the "A" and "B" dusts. As already noted by Quayle (1924) in a previous number of this publication, very few of the fallen hoppers recover when the ground is covered with particles of calcium cyanide dust. In the case of the nymphs however it was observed that many do not fall from the foliage, as do the adults, but remain clinging to it even when dead.

J. R. Eyer, *Entomologist,*
North East Lab., Pa. Dept. of Agriculture, North East, Pennsylvania

PEAR PSYLLA

Field experiments in the control of the Pear Psylla, *Psylla pyricola*, with Cyanogas Calcium Cyanide Dust, were conducted by Professor F. G. Mundinger and recorded in his paper reproduced on pages 6-4 to 6-8. He continued his work in 1924, publishing his second report in the Proceedings of the 70th Annual Meeting of the New York State Horticultural Society, 1925, pp. 182-186.

Fig. 4-6.—Control of Pear Psylla in New York State with Cyanogas Dust. Note Drift of Dust Through the Orchard.

The data given in Professor Mundinger's second report, with additional experiments presented in greater detail, have been published as Bulletin 529, New York State Agricultural Experiment Station, July, 1925. Cyanogas Calcium Cyanide "B" Dust, with which Professor Mundinger obtained the favorable results reported in this bulletin, has been superseded in the trade by Cyanogas S-Dusting Mixture, a dust with the same calcium cyanide content as "B" Dust (see page G-2). Cyanogas S-Dusting Mixture, in addition to its insecticidal properties, is a fungicide due to its sulphur content.

BULLETIN NO. 529 JULY, 1925

New York State Agricultural Experiment Station

GENEVA, N. Y.

INVESTIGATIONS ON THE CONTROL OF PEAR PSYLLA

F. G. MUNDINGER

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Bulletin No. 529

INVESTIGATIONS ON THE CONTROL OF PEAR PSYLLA

F. G. MUNDINGER

SUMMARY

This bulletin presents data obtained from scheduled treatments with various dust and spray materials for the control of the pear psylla (*Psylla pyricola* Förster) in the McKay orchard in the vicinity of Geneva during the season of 1924. This pest presents a difficult problem because of its great ability to reproduce, its resistance on account of certain habits of the nymphs to many of the common insecticides and spray methods, and the migratory activities of the adults or "flies." The occurrence of the insect in several different stages of development during the summer adds to the difficulty of control.

A new model, self-mixing, power duster was used for dusting and a large power sprayer for making the liquid applications. Spur counts were made where possible, before and after each application, and the reduction in the number of nymphs was used as a criterion of the effectiveness of the different materials employed. Leaf counts were also made at the end of the experiment to determine, if possible, the amount of injury caused by the insects and by the various dust and spray materials used.

None of the dusts appeared to control the species in the egg or early nymphal stages. Lime sulfur (1 to 8) killed many eggs. The weak bordeaux sprays and the dry-mix sprays containing nicotine sulfate were very effective against the nymphs. Tobacco dust appeared to be a factor of effectiveness when added to the various sprays in combating the nymphs. Little injury was caused by any of the materials, except lime-sulfur sprays and some of the oil applications.

A number of experiments are also described in which calcium cyanide dusts of various grades were compared with other dusting materials and with spray mixtures for the control of psylla in the vicinity of Geneva and in the Hudson River Valley.

Calcium cyanide dusts grades "A" and "B" and nicotine dusts, under favorable conditions, proved very toxic to the adults. "A" and "B" grades of calcium cyanide dusts averaged greater reductions in

tree population and smaller percentages of revival than did a home-made lime-nicotine dust containing 2 per cent nicotine or a commercial mixture containing 2.7 per cent nicotine.

The best results with dusting were obtained on calm days when the temperature was relatively high. A dosage of 2 pounds of "B" grade calcium cyanide, a minimum of 1½ pounds of "A" grade calcium cyanide, or 2 pounds of lime-nicotine dust (2 per cent) per average-sized tree is advisable for best results. None of the above dusts where carefully applied caused noticeable injury to mature foliage. "A" grade calcium cyanide dust caused some blackening of young, tender leaves when used early in the season.

INTRODUCTION

Work has been done with lime-sulfur and nicotine sprays and with nicotine dusts in combating the pear psylla. The dry-mix formula has also been used with promising results. With the appearance of a new dust, calcium cyanide, it seemed advisable to try this new material in a number of scheduled applications along with some standard sprays and a few other spray mixtures. The applications were aimed mostly at the eggs and nymphs.

The particular orchard[1] treated is owned by the McKay brothers and is but a short distance from the Experiment Station. It consists of about 600 Bartlett trees, 15 years old, and covers 6.7 acres. The accompanying diagram (Fig. 1) shows the experimental rows and the general environment of the orchard. The plats consist of one or two rows of 20 trees each.

All treatments were timed according to the development of the psylla. The materials were furnished by the Experiment Station and were applied by competent Station workers. New model power dusters and sprayers were used in this work.

Calcium cyanide as an insecticide dust was first tested against pear psylla under the direction of the Experiment Station during the summer of 1923 The material reacts with atmospheric moisture producing hydrocyanic acid gas, a rank poison to animal life. This gas is produced also by a combination of sulfuric acid and potassium or sodium cyanide and fumigation with hydrocyanic acid gas has been one of the principal methods used for the treatment of buildings.

[1]For further details about this orchard see Circular No. 65 of this Station.
Acknowledgments are due to Miss Middlewood, Geneva, N. Y., McKay Brothers, Geneva, N. Y., and Mr. L. Fingar, North Germantown, N. Y., for the use of their orchards and for cooperation in this work.

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The first experimental work involving the use of hydrocyanic acid gas against the pear psylla was probably done by R. L. Webster[2] (1918 to 1920), who used large fumigation tents placed over trees and generated the gas by the old fumigation methods.

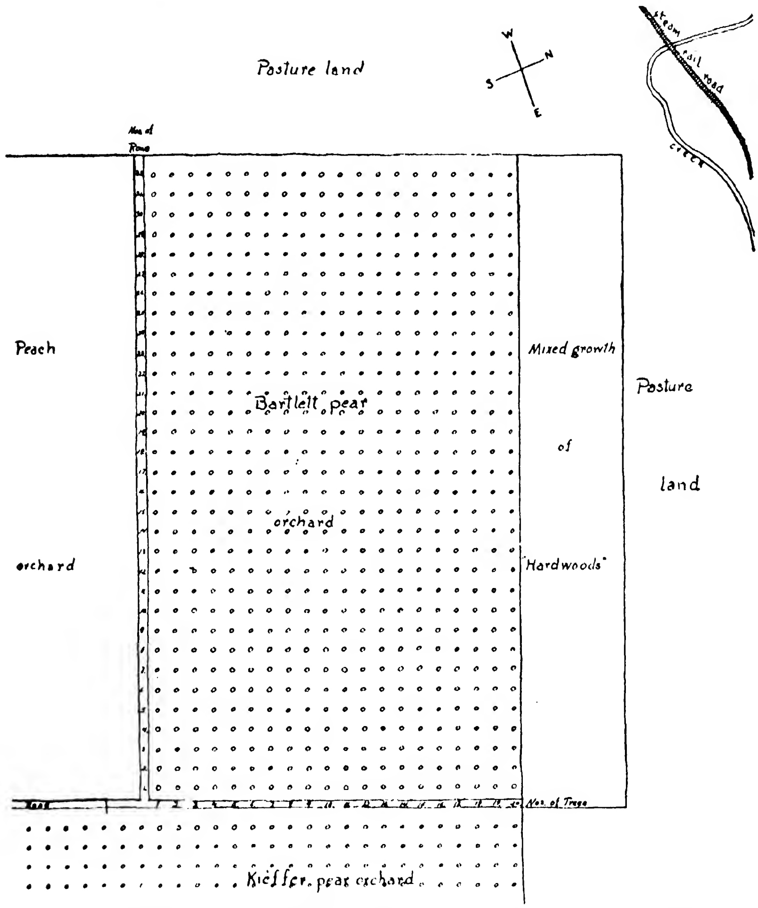

FIG. 1.—DIAGRAM OF THE MCKAY ORCHARD AND IMMEDIATE ENVIRONMENT.

During the summer of 1923 some promising results were obtained with calcium cyanide for psylla which prompted further investigation of the chemical during the next season. The experiments herein

[2]Fumigation with hydrogen cyanide for control of pear psylla. Bulletin No. 523 of this Station.

described are more or less scattered as to time and place. The chief end of the work was to compare results obtained with calcium cyanide under varying conditions with some other materials, such as hydrated lime dust, nicotine dusts, and one or two sprays. The sprays were selected because of their scheduled time of application and their effectiveness.

Both power and hand dusters were used. A "power" sprayer served for making the liquid treatments. In some instances ordinary cheesecloth strips were used for catching the dislodged insects, but in most trials paper plates were arranged under the selected trees for this purpose. Revival boxes of various types were improvised. The one found to be most satisfactory was a four-sided box about 5 inches high with a cheesecloth bottom and open at the top. The cheesecloth was about 30-mesh to the inch, coarse enough to allow the dust to fall thru but retain the psyllas.

MATERIALS USED

The following dust preparations and spray materials were used:

Dust: Calcium cyanide, grade "C," 25 per cent calcium cyanide and 75 per cent talc.

Dust: Calcium cyanide, grade "B," 50 per cent calcium cyanide and 50 per cent talc.

Dust: Calcium cyanide, grade "A," 100 per cent calcium cyanide.

Dust: Hydrated lime, commercial, very finely ground.

Dust: Calcium cyanide, "C" grade, 25 pounds; hydrated lime, 25 pounds; Black Leaf 40, 2½ pounds.

Spray: Lime-sulfur, 15 gallons; water, 100 gallons.

Spray: Lime-sulfur, 3 gallons; water, 100 gallons.

Spray: Lime-sulfur, 15 gallons; tobacco dust, 14 pounds; water, 100 gallons.

Spray: Lime-sulfur, 3 gallons; tobacco dust, 14 pounds; arsenate of lead, 2½ pounds; water, 100 gallons.

Spray: Lime-sulfur, 3 gallons; arsenate of lead, 2½ pounds; Black Leaf 40, 1 pint; water, 100 gallons.

Spray: Lime-sulfur, 3 gallons; tobacco dust, 14 pounds; water, 100 gallons.

Spray: Lime-sulfur, 3 gallons; Black Leaf 40, 1 pint; water, 100 gallons.

Spray: Paraffin oil, 2 gallons; water, 1 gallon; potash soap, 2 pounds; water, 100 gallons.

Spray: Copper sulfate, 2 pounds; lime, 30 pounds; water 100 gallons.

Spray: Super-fine sulfur, 16 pounds; hydrated lime, 8 pounds; Kayso, 1 pound; arsenate of lead, 2½ pounds; Black Leaf 40, 1 pint; water, 100 gallons.

Spray: Super-fine sulfur, 16 pounds; hydrated lime, 8 pounds; Kayso, 1 pound; arsenate of lead, 2½ pounds; Black Leaf 40, 1 pint, hydrated lime, 30 pounds; water, 100 gallons.

Spray: Super-fine sulfur, 16 pounds; hydrated lime, 8 pounds; Kayso, 1 pound; Black Leaf 40, 1 pint; water, 100 gallons.

Spray: Super-fine sulfur, 16 pounds; hydrated lime, 8 pounds; Kayso, 1 pound; Black Leaf 40, 1 pint; hydrated lime, 30 pounds; water, 100 gallons.

Spray: Copper sulfate, 2 pounds; lime, 30 pounds; Black Leaf 40, 1 pint; water, 100 gallons.

Spray: Paraffin oil, 2 gallons; water, 1 gallon; potash soap, 2 pounds; water, 200 gallons.

Spray: Super-fine sulfur, 16 pounds; hydrated lime, 8 pounds; Kayso, 1 pound; tobacco dust, 14 pounds; water, 100 gallons.

PROCEDURE

The machines for delivering the insecticidal materials were carefully driven up and down between the rows of trees and applications made from two sides of the trees. An effort was made to give each tree an equal coating of material, according to the dosage planned. Dusts requiring mixing were mixed in the dusting machine in the field.

A definite number of spurs, selected at random from each plat, were examined before and after each treatment wherever possible. At first, 25 spurs were examined for each material used, but as time would not allow for such extensive observations, a minimum of 10 spurs was sometimes used. Each spur was carefully searched for psylla eggs and nymphs and the number of specimens in the various instars noted and recorded.

I. SPRAYING VS. DUSTING IN THE McKAY ORCHARD

FIRST APPLICATION

On May 14, 1924, when the first application was made, the trees were in the dormant state. Few flies were seen, tho many eggs had been laid and some had hatched. The cluster buds were well hidden by the bud scales. Some of the newly hatched nymphs had found their way to the bases of the pedicels of the unopened blossom clusters. This treatment was timed mostly for the destruction of the psylla eggs. The maximum and minimum temperatures for the day were 65°F. and 49°F., respectively. The humidity was relatively high. Counts were made from 20 spurs of each plat. The materials used and the data obtained are given in Table 1.

TABLE 1.—RESULTS OBTAINED WITH FIRST APPLICATION OF DUSTS AND SPRAYS FOR PEAR PSYLLA IN THE MCKAY ORCHARD IN 1924.

ROW NO.	MATERIAL	DOSAGE IN POUNDS OR GALLONS PER TREE	DATE OF APPLICATION	DATE OF COUNT	NUMBER OF PSYLLA NYMPHS IN INSTARS 1 and 2	3	4 and 5	NUMBER OF ADULTS	REMARKS
	Dusts								
1 and 2	Hydrated lime	2½	May 14	May 14–17	63	—	—		100 eggs on side of leaf 10 dead larvae
3	Calcium cyanide "C" grade	¾	May 14	May 14–17	19	—	—	Few	Many new eggs on leaves and blossom stems
4a	Calcium cyanide "B" grade	1	May 14	May 14–17	13	—	—	flies	
4b	Calcium cyanide "A" grade	1	May 14	May 14–17	8	—	—	seen	67 new eggs
	Sprays								
5 and 6	Lime-sulfur and tobacco dust	5	May 15	May 15–17	6	—	—		
7 and 8	Lime-sulfur, 1–8	5	May 15	May 15–17	63	—	—		
9 and 10	Paraffin oil emulsion 2 per cent	5	May 15	May 15–17	95	—	—		Many larvae killed; many new eggs
Check	———	—	—	May 15–17	257	—	—		

It will be noted in a study of the table that the time of observation continued over several days and that during this period there were newly laid and newly hatched eggs which complicated the work of counting. For this reason the data are considered suggestive only. A comparison of check trees and treated trees indicates, however, that either many eggs were killed by certain of the materials or that a considerable number of the young nymphs on hatching from the eggs succumbed to the residues of the different treatments that still remained on the bark at the time of hatching.

On May 19 Bartlett pears were beginning to blossom. Many psylla eggs were found and approximately 50 per cent of all the eggs had hatched. Young nymphs were numerous in the axils of the blossom clusters. Hydrated lime encrusted on the eggs seemed to have killed many of them. Many collapsed eggs were noticed on the plats sprayed with lime-sulfur. Calcium cyanide "A" grade caused some injury to the tips of unfolding leaves and appeared quite similar to injury from lime-sulfur, but not so severe.

Observations on May 22 revealed that since the spray was applied there had been a heavy deposition of eggs. Many of these were laid on the unfolding leaves. All the sprays seemed to have killed many eggs or to have caused the death of the nymphs at the time of hatching. Some discoloration of the blossom stems due to oil was noticed.

On June 9 the leaves were fully expanded and there was a good cover of foliage, tho few of the insects had reached the adult stage the greater majority being in the hard-shell stage.

SECOND APPLICATION

The same series of dusts as used in the first application was applied to the original block of trees in the second application made on June 9. To the spray mixture used on Rows 5 and 6 arsenate of lead was added; to that on Rows 7 and 8, Black Leaf 40 and lead arsenate were added; while on Rows 9 and 10 copper sulfate and lime replaced the oil spray.

The dry-mix sprays were applied to the next two plats as shown in Table 2. At this time a previously untreated block of pears, Rows 15 to 20, inclusive, was given a series of dust treatments similar to that applied to the first block. Dusting began at 10 a. m. It was a warm day, the maximum and minimum temperatures being 71°F. and 42°F., respectively, and a slight breeze was stirring. The dry-mix sprays were applied on the next day when the general weather conditions were similar to those of the previous day. Counts were made from 25 spurs of each plat, except the check plat on which only 20 were counted. The data obtained are given in Table 2.

TABLE 2.—RESULTS OBTAINED WITH SECOND APPLICATION OF DUSTS AND SPRAYS FOR PEAR PSYLLA IN THE MCKAY ORCHARD IN 1924

Row no.	Material	Dosage in pounds or gallons per tree	Date of application	Date of count	Number of psylla nymphs in instars: 1 and 2	3	4 and 5	Total number of nymphs	Number of adults	Percentage soft-shells	Percentage hard-shells	Percentage adults	Remarks
	Dusts												
1 and 2	Hydrated lime	1	June 9	June 9	126	40	42	208	0	79.7	20.1	0	
3	Calcium cyanide "C" grade	¾	June 9	June 9	139	51	43	233	1	81.1	18.3	0.427	
4a	Calcium cyanide "B" grade	¾	June 9	June 9	75	36	43	154	0	72	27.9	0	Some honey-dew present
4b	Calcium cyanide "A" grade	½	June 9	June 10	138	25	20	183	1	88.5	10.86	0.54	
	Sprays												
5 and 6	Lime-sulfur, lead, and tobacco dust	5	June 9	June 10	20	7	10	37	3	67.5	25	7.5	
7 and 8	Lime-sulfur, lead, and Black Leaf 40	5	June 9	June 11	9	0	12	21	0	42.8	57.1	0	A little honey-dew
9 and 10	Copper sulfate and lime, 2–30–100	5	June 9	June 11	0	0	4	4	0	0	100	0	Several dead nymphs
11 and 12	Dry-mix, lead, Kayso, and Black Leaf 40	5	June 10	June 11	0	0	8	8	0	0	100	0	Many dead nymphs; some honey-dew
13 and 14	Dry-mix, lead, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	5	June 10	June 11	12	1	13	26	0	50	50	0	Many dead nymphs; some honey-dew
	Dusts												
15 and 16	Hydrated lime	1	June 9	June 12	43	13	139	195	4	28.2	69.8	2.01	Much honey-dew
17	Calcium cyanide "C," lime, and Black Leaf 40	1	June 9	June 12	8	15	139	162	6	13.6	82.7	3.57	Much honey-dew; many dead nymphs
18	Calcium cyanide "C" grade	¾	June 9	June 12	44	49	266	359	19	24.6	70.3	5.02	Some honey-dew
20b	Calcium Cyanide "B" grade	¾	June 9	June 12	7	11	105	123	9	13.6	79.5	6.81	Some honey-dew
20a	Calcium cyanide "A" grade	½	June 9	June 12	11	39	185	235	12	20.2	74.8	4.85	Much honey-dew
Check	———	—	—	June 12	56	50	269	375	6	27.8	70.6	1.57	Much honey-dew

It is interesting to compare the data of the two dusted blocks. In the original block the majority of psylla were in the first nymphal stages, while in the second block by far the greater number had reached the hard-shell stage. This indicates that all the materials used in the treatments of Block 1 killed some of the eggs and nymphs. The sprays in general showed the best control. The plat treated with copper sulfate and lime appeared freest from psylla. A hard rain storm on the evening of June 9 undoubtedly washed away some of the insecticides and also some of the psylla nymphs, which facts should be taken into consideration with respect to the data taken directly after June 9.

By June 16 the young fruits had set and some of them were developing rapidly. A few of the insects of the first block of trees had reached the adult stage, and approximately half of those of the second block were mature. Honey-dew was present in noticeable quantities in the dusted plats and some was seen in the sprayed plats. Table 3 gives the data resulting from these observations.

THIRD APPLICATION

Dusts and sprays were applied as shown in Table 4 for the third application made on June 20. The dusting operations began about 9 a. m. The maximum and minimum temperatures for the day were 91° F. and 58° F., respectively, and there was a slight breeze. The sprays were applied on the next day, atmospheric conditions being unchanged except for cloudiness. Some of the sprays were altered a little as shown in the table. Counts were made from 20 spurs on each plat. The data obtained are shown in Table 4.

Observations showed that the best control of the psylla nymphs was obtained in the sprayed plats. The large reduction percentages found in the second block of dusted plats were undoubtedly augmented by the severe beating rain which came on the evening that the treatments were made. The increase in the number of adults shown after treatment was very likely due to migration.

On July 15 the adult flies were disregarded and all attention given to the nymphs. In order to secure more accurate data, a definite number of leaf spurs from each plat was taken to the laboratory and carefully examined with the aid of a lens. Heavy oviposition was again taking place and many of the eggs had hatched. All plats supported a considerable number of new nymphs. The plat treated with copper and lime appeared to have fewer than any of the other dusted

TABLE 3.—OBSERVATIONS A WEEK FOLLOWING THE SECOND APPLICATION OF DUSTS AND SPRAYS IN THE MCKAY ORCHARD IN 1924.

Row no.	Material	Dosage in pounds or gallons per tree	Date of application	Date of count	Number of psylla nymphs in instars: and 2	Number of psylla nymphs in instars: 3	Number of psylla nymphs in instars: 4 and 5	Total number of nymphs	Number of adults	Percentage soft-shells	Percentage hard-shells	Percentage adults	Remarks
	Dusts												
1 and 2	Hydrated lime	1	June 9	June 16	3	16	87	106	20	15.07	69.04	15.8	Much honey-dew
3	Calcium cyanide "C" grade	¾	June 9	June 16	20	36	73	129	14	39.1	51.04	9.79	Much honey-dew
4a	Calcium cyanide "B" grade	¾	June 9	June 16	3	17	38	58	12	28.5	54.2	17.1	Much honey-dew
4b	Calcium cyanide "A" grade	1	June 9	June 16	1	12	31	44	4	27.08	64.5	8.33	Some honey-dew
	Sprays												
5 and 6	Lime-sulfur, lead, and tobacco dust	5	June 9	June 16	0	2	2	4	1	40	40	20	Some honey-dew
7 and 8	Lime-sulfur, lead, and Black Leaf 40	5	June 9	June 16	0	0	0	0	4	0	0	100	
9 and 10	Copper sulfate and lime, 2–30–100	5	June 9	June 17	0	0	2	2	6	0	25	75	
11 and 12	Dry-mix, lead, Kayso, and Black Leaf 40	5	June 10	June 17	0	1	7	8	11	5.26	36.8	57.8	Many dead nymphs, some honey-dew
13 and 14	Dry-mix, lead, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	5	June 10	June 17	0	0	3	3	1	0	75	25	Many dead nymphs; some honey-dew
	Dusts												
15 and 16	Hydrated lime	1	June 9	June 17	14	7	64	85	84	12.4	37.8	49.7	Much honey-dew
17	Calcium cyanide, "C" grade, lime, and Black Leaf 40	1	June 9	June 17	9	3	23	35	38	16.4	31.5	52.05	Much honey-dew
18	Calcium cyanide "C" grade	¾	June 9	June 17	0	9	74	83	47	6.92	56.9	36.1	Much honey-dew
20b	Calcium cyanide "B" grade	¾	June 9	June 17	8	3	35	46	10	19.8	62.5	17.8	Much honey-dew
20a	Calcium cyanide "A" grade	1	June 9	June 17	9	5	68	82	64	9.58	46.5	43.8	Much honey-dew
Check	———	—	—	June 17	4	5	114	123	53	5.11	64.7	30.1	Much honey-dew

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Table 4.—Results Obtained with Third Application of Dusts and Sprays for Pear Psylla in the McKay Orchard in 1924.

Row no.	Materiai	Dosage in pounds or gallons per tree	Date of application	Date of count	Number of psylla nymphs in instars: 1 and 2	3	4 and 5	Total number of nymphs	Number of adults	Percentage soft-shells	Percentage hard-shells	Percentage adults	Remarks
	Dusts												
1 and 2	Hydrated lime	1	June 20	June 20	8	14	47	69	51	18.3	39.1	42.5	Some honey-dew; a few dead nymphs
3	Calcium cyanide "C" grade	½	June 20	June 20	11	22	49	82	21	32.03	47.5	20.3	
4a	Calcium cyanide "B" grade	¾	June 20	June 21	1	2	15	18	11	10.34	51.7	37.9	Some honey-dew
4b	Calcium cyanide "A" grade	½	June 20	June 21	6	8	13	27	9	38.8	36.1	25	Some honey-dew; many dead nymphs
	Sprays												
5 and 6	Lime-sulfur and tobacco dust	5	June 21	June 26	0	0	0	0	40	0	0	100	
7 and 8	Lime-sulfur, lead, and Black Leaf 40	5	June 21	June 26	0	0	0	0	18	0	0	100	
9 and 10	Copper sulfate and hydrated lime	5	June 21	June 26	0	0	0	0	14	0	0	100	
11 and 12	Dry-mix, Kayso, and Black Leaf 40	5	June 21	June 26	0	0	0	0	18	0	0	100	
13 and 14	Dry-mix, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	5	June 21	June 26	0	0	0	0	29	0	0	100	
	Dusts												
15 and 16	Hydrated lime	1	June 20	June 21	5	1	7	13	60	8.21	9.58	82.1	Some honey-dew; a few dead nymphs
17	Calcium cyanide, lime, and Black Leaf 40	1	June 20	June 21	1	0	2	3	50	1.88	3.77	94.3	
18	Calcium cyanide "C" grade	½	June 20	June 21	3	4	10	17	79	7.29	10.41	82.2	Some honey-dew
20b	Calcium cyanide "B" grade	¾	June 20	June 26	0	0	0	0	31	0	0	100	
20a	Calcium cyanide "A" grade	½	June 20	June 26	0	1	8	9	58	1.49	11.9	86.5	
Check	———	—	—	June 26	0	1	12	13	91	0.96	11.5	87.5	Many new eggs found

SUMMARY OF TABLES 3 AND 4.

Row no.	Material	Count before application		Count after application		Decrease in number of nymphs	Increase or decrease in number of adults	Percentage reduction in number of nymphs	Percentage reduction in number of insects
		Nymphs	Adults	Nymphs	Adults				
	Dusts								
1 and 2	Hydrated lime	106	20	69	51	37	+31	34.9	4.7
3	Calcium cyanide "C" grade	129	14	82	21	47	+ 7	36.4	27.9
4a	Calcium cyanide "B" grade	58	12	18	11	40	— 1	68.9	58.5
4b	Calcium cyanide "A" grade	44	4	27	9	17	+ 5	38.6	25
	Sprays								
5 and 6	Lime-sulfur and tobacco dust	4	1	0	40	4	+39	100	—
7 and 8	Lime-sulfur, lead, and Black Leaf 40	0	4	0	18	0	+14	0	—
9 and 10	Copper sulfate and hydrated lime	2	6	0	14	2	+ 8	100	—
11 and 12	Dry-mix, Kayso, and Black Leaf 40	8	11	0	18	8	+ 7	100	—
13 and 14	Dry-mix, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	3	1	0	29	3	+28	100	—
	Dusts								
15 and 16	Hydrated lime	85	84	13	60	72	—24	84.7	56.8
17	Calcium cyanide, lime, and Black Leaf 40	35	38	3	50	32	+12	91.4	27.3
18	Calcium cyanide "C" grade	83	47	17	79	66	+32	79.5	26.1
20b	Calcium cyanide "B" grade	46	10	0	31	46	+21	100	44.6
20a	Calcium cyanide "A" grade	82	64	9	58	73	— 6	89	54.1
Chekc	———	123	53	13	91	—	—	—	—

6-23

or sprayed plats. It is quite possible that the coating of lime played an important part here. The appearance of large numbers of nymphs in all plats seems to confirm the idea that adult psylla move from tree to tree quite freely. The data from these observations are given in Table 5.

FOURTH APPLICATION

The fourth application was made on July 16 when the dusted blocks received the same treatment as before. Dusting began about 1:20 p. m. It was warm and sunny and a breeze was stirring. The maximum and minimum temperatures for the day were 83°F. and 56°F., respectively. The sprays were applied on the next day. A rather strong wind interfered with thoro work. Changes made in the various spray materials will be noted on comparing Tables 5 and 6. New sprays were applied to former check plats. Ten spurs of each plat were carefully examined at the laboratory. The data obtained are shown in Table 6. No counts were made in Block 2.

It is evident from the data that the sprays noticeably reduced the number of psylla nymphs, while the dusts did not show any striking results. Good control was obtained with the copper-lime and with the dry-mix sprays containing nicotine. One dust, calcium cyanide, lime, and Black Leaf 40, gave a hint of control. Some injury was noticed in the lime-sulfur treated plat.

INJURY TO FOLIAGE

An effort was made to obtain some idea of the degree of injury to the foliage caused by the various dust and spray materials by the time the last applications had been made. To accomplish this a number of branches were examined in each plat. The observations were limited to the distal 2 feet of each branch. The number of spurs and leaves were counted, and the number of psylla-injured leaves and of dust- or spray-injured leaves noted. An estimate was made of the average amount of injury of each kind. The data derived in this way are shown in Table 7.

These figures do not show any of the early injury caused by treatments made when the foliage was just opening. It may be stated that lime-sulfur 1 to 8 caused some burning of the tips and margins of the leaves; and that calcium cyanide "A" grade, especially where applied heavily, caused an injury similar in appearance to that of lime-sulfur but not so bad. It will be noticed from the table that Rows 9 to 13

TABLE 7.—DATA ON PSYLLA INJURY AND ON SPRAY OR DUST INJURY ON 20 BRANCHES FROM EACH PLAT IN THE MCKAY ORCHARD IN 1924.

Row No.	Material (Last Application	Number of Spurs Counted	Total Number of Leaves	Number of Leaves Injured by Psylla	Percentage of Leaf Area Injured by Psylla	Number of Leaves Injured by Dust or Spray Materials	Percentage of Leaf Area Injured by Dusts or Sprays
	Dusts						
1	Hydrated lime	327	1,283	831	5.3	0	0
3	Calcium cyanide "C" grade	310	1,250	709	4.41	0	0
4a	Calcium cyanide "B" grade	337	1,263	540	1.57	0	0
4b	Calcium cyanide "A" grade	282	1,204	468	1.56	0	0
15	Hydrated lime	301	1,206	550	3.11	0	0
17	Calcium cyanide, lime, and Black Leaf 40	303	1,312	617	2.59	0	0
	Sprays						
5	Lime-sulfur and tobacco dust	281	1,063	478	1.8	547	3.97
7	Lime-sulfur, lead, and Black Leaf 40	276	1,093	378	1.13	769	9.32
9	Bordeaux and Black Leaf 40	295	1,160	167	0.25	0	0
13	Dry-mix and tobacco dust	280	1,234	157	0.18	0	0
14	Dry-mix, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	303	1,337	408	1.15	0	0
23	Lubricating oil emulsion, 1 per cent	298	1,291	768	3.64		
25	Lubricating oil emulsion, 2 per cent	308	1,254	649	2.13		
26	Lime-sulfur, 1–40	276	1,185	644	2.09	721	5.4
27	Lime-sulfur and Black Leaf 40	262	1,142	658	2.12	577	2.06

Summary of Tables 5 and 6.

Row no.	Materials	Number of nymphs before application	Number of nymphs after application	Decrease in number of nymphs	Percentage reduction in number of nymphs
	Dusts				
1 and 2	Hydrated lime	307	195	112	36
3	Calcium cyanide "C" grade	262	104	158	60.3
4a	Calcium cyanide "B" grade	251	351	—	—
4b	Calcium cyanide "A" grade	304	176	128	42.1
17	Calcium cyanide "C" grade, lime, and Black Leaf 40	255	39	216	84.7
	Sprays				
9 and 10	Bordeaux and Black Leaf 40	163	12	151	92.6
12	Dry-mix and Black Leaf 40	260	2	258	99.2
13	Dry-mix and tobacco dust	259	0	259	100
23	Lubricating oil emulsion, 1 per cent	—	27	—	—
25	Lubricating oil emulsion, 2 per cent	—	5	—	—
27	Lime-sulfur, 1–40	—	19	—	—
28	Lime-sulfur and Black Leaf 40	—	6	—	—
Check	———	—	—	—	—

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SUMMARY OF TABLES 5 AND 6.

Row no.	Materials	Number of nymphs before application	Number of nymphs after application	Decrease in number of nymphs	Percentage reduction in number of nymphs
	Dusts				
1 and 2	Hydrated lime	307	195	112	36
3	Calcium cyanide "C" grade	262	104	158	60.3
4a	Calcium cyanide "B" grade	251	351	—	—
4b	Calcium cyanide "A" grade	304	176	128	42.1
17	Calcium cyanide "C" grade, lime, and Black Leaf 40	255	39	216	84.7
	Sprays				
9 and 10	Bordeaux and Black Leaf 40	163	12	151	92.6
12	Dry-mix and Black Leaf 40	260	2	258	99.2
13	Dry-mix and tobacco dust	259	0	259	100
23	Lubricating oil emulsion, 1 per cent	—	27	—	—
25	Lubricating oil emulsion, 2 per cent	—	5	—	—
27	Lime-sulfur, 1–40	—	19	—	—
28	Lime-sulfur and Black Leaf 40	—	6	—	—
Check	———	—	—	—	—

TABLE 7.—DATA ON PSYLLA INJURY AND ON SPRAY OR DUST INJURY ON 20 BRANCHES FROM EACH PLAT IN THE McKAY ORCHARD IN 1924.

ROW NO.	MATERIAL (LAST APPLICATION	NUMBER OF SPURS COUNTED	TOTAL NUMBER OF LEAVES	NUMBER OF LEAVES INJURED BY PSYLLA	PERCENTAGE OF LEAF AREA INJURED BY PSYLLA	NUMBER OF LEAVES INJURED BY DUST OR SPRAY MATERIALS	PERCENTAGE OF LEAF AREA INJURED BY DUSTS OR SPRAYS
	Dusts						
1	Hydrated lime	327	1,283	831	5.3	0	0
3	Calcium cyanide "C" grade	310	1,250	709	4.41	0	0
4a	Calcium cyanide "B" grade	337	1,263	540	1.57	0	0
4b	Calcium cyanide "A" grade	282	1,204	468	1.56	0	0
15	Hydrated lime	301	1,206	550	3.11	0	0
17	Calcium cyanide, lime, and Black Leaf 40	303	1,312	617	2.59	0	0
	Sprays						
5	Lime-sulfur and tobacco dust	281	1,063	478	1.8	547	3.97
7	Lime-sulfur, lead, and Black Leaf 40	276	1,093	378	1.13	769	9.32
9	Bordeaux and Black Leaf 40	295	1,160	167	0.25	0	0
13	Dry-mix and tobacco dust	280	1,234	157	0.18	0	0
14	Dry-mix, Kayso, and Black Leaf 40 plus 30 pounds hydrated lime	303	1,337	408	1.15	0	0
23	Lubricating oil emulsion, 1 per cent	298	1,291	768	3.64		
25	Lubricating oil emulsion, 2 per cent	308	1,254	649	2.13		
26	Lime-sulfur, 1–40	276	1,185	644	2.09	721	5.4
27	Lime-sulfur and Black Leaf 40	262	1,142	658	2.12	577	2.06

inclusive, have a smaller percentage of leaf injury than any of the other rows. The injury to mature foliage by the dusts used is practically negligible. Since the plats from Row 22 on received only one treatment, it is unfair to compare them with any of the other treated plats with respect to either psylla or spray injury. On the whole, the lime-sulfur sprays were the only ones to cause injury to a noticeable degree. Oil sprays showed marked traces of injury at times. None of the spray injury was serious.

COST OF MATERIALS

The costs of the spray and dust materials used in these experiments are given in Table 8.

TABLE 8.—COST OF MATERIALS USED IN MCKAY ORCHARD IN 1924.

MATERIAL	COST PER POUND OR GALLON
Hydrated lime dust	$0.01
Calcium cyanide dust "C" grade	0.13
Calcium cyanide dust "B" grade	0.16
Calcium cyanide dust "A" grade	0.19
Calcium cyanide dust with hydrated lime and Black Leaf 40.	0.125
Lime-sulfur spray 1 to 8	0.0260
Lime-sulfur spray 1 to 8 and tobacco dust	0.0316
Lime-sulfur spray 1 to 40	0.0058
Lime-sulfur spray 1 to 40 and tobacco dust	0.0112
Lime-sulfur spray 1 to 40, lead arsenate, and tobacco dust	0.0162
Lime-sulfur spray 1 to 40, lead arsenate, and Black Leaf 40	0.0240
Lime-sulfur spray and Black Leaf 40	0.0191
Lubricating oil spray, 2 per cent	0.0043
Lubricating oil spray, 1 per cent	0.0021
Copper sulfate and lime spray, 2–30–100	0.0042
Copper sulfate and lime spray, 2–30–100, with Black Leaf 40	0.01798
Dry-mix and Black Leaf 40	0.0204
Dry-mix spray and Black Leaf 40 plus hydrated lime 30 pounds	0.0234
Dry-mix spray, lead, and Black Leaf 40	0.0255
Dry-mix spray, lead, Black Leaf 40, and hydrated lime 30 pounds	0.0285
Dry-mix and tobacco dust	0.0123

SUMMARY AND CONCLUSIONS

Since the spring of 1924 was an exceptionally wet and stormy one, it is feared that the data secured are not as representative as might be desired. There is no doubt but that many of the smaller nymphs, not being securely anchored or supported by foliage, were washed to the ground during hard storms. Because of the proximity of the plats in the McKay orchard, it was very possible that psylla adults disturbed in one area departed for more quiet locations. This

probably accounts for some of the sudden infestations observed.

The dusts did not appear to give satisfactory control of the psylla nymphs. The calcium cyanide-lime-Black Leaf 40 dust seemed most promising of any of the dusts in this respect. The honey-dew surrounding the young psylla seems in many instances to be a barrier to dusts. All sprays used showed good killing properties. Lime-sulfur and nicotine applied at the cluster bud stage was the most effective against the eggs. The copper-lime plats and the dry-mix plats (treated at the calyx period) showed the best controls.

Tho some burning was occasioned by dusts in the early applications, this was not extensive. Mature leaves were not noticeably burned, except where very heavy deposits of "A" cyanide dusts occurred. Some injury was caused by oils, but the most noticeable effects were produced by lime-sulfur sprays. In no case was the injury serious.

II. CALCIUM CYANIDE DUSTING

INDIVIDUAL EXPERIMENTS IN MCKAY ORCHARD

Experiment 1, June 10.—Several dusts were applied with a small hand bellows duster about 10:30 a. m. The maximum and minimum temperatures for the day were 77°F. and 44°F., respectively. There was a light breeze and the day was clear and sunny. Three spurs each were selected from three separate trees and were well dusted. Each spur was tagged and examined before and after the treatment. The data obtained are shown in Table 9.

"A" grade calcium cyanide dust appears to have given the best results of any of the treatments. A hard rain on the afternoon of June 11 no doubt affected the results somewhat.

Experiment 2, June 18.—The same type of small duster was again employed for the treatments, which occurred at 9 a. m. The maximum and minimum temperatures for the day were 81°F. and 53°F., respectively. It was a warm day and a light breeze was stirring. Five spurs were treated with each material. They were well coated with dust and tagged. Counts were made two days later. The data are shown in Table 9.

"A" grade calcium cyanide dust was the most toxic to the young nymphs. Both "A" and "B" dusts seemed to affect the hard-shells more than the younger nymphs.

TABLE 9.—CYANIDE DUSTING EXPERIMENTS IN THE MCKAY ORCHARD.

Material	Count before application					Count after application						Percentage reduction of nymphs	Percentage loss or gain of adults	Percentage reduction of insects
	Number of nymphs	Number of adults	Percentage soft-shells	Percentage hard-shells	Percentage adults	Number of live nymphs	Number of dead nymphs	Number of adults	Percentage soft-shells	Percentage hard-shells	Percentage adults			
Experiment 1—June 10														
Hydrated lime	78	0	44.8	55.1	0	47	4	2	24.4	71.8	4.08	39.7	+200	37.1
Calcium cyanide "C" dust	113	0	72.5	27.4	0	36	0	0	50	50	0	68.1	0	68.1
Calcium cyanide "B" dust	76	0	50	50.0	0	33	25	0	9.09	90.9	0	56.5	0	56.5
Calcium cyanide "A" dust	80	0	52.5	47.5	0	19	11	1	20	75	5	76.2	+100	75
Check	82	0	31.9	68.2	0	82	0	4	3.51	91.8	4.65	—	—	—
Experiment 2—June 18														
Hydrated lime	53	0	15.09	84.9	0	48	9	3	13.7	80.39	5.88	9.43	+300	3.77
Calcium cyanide "C" dust	41	4	8.88	82.2	8.88	25	9	11	22.2	47.2	30.55	39.02	+175	20
Calcium cyanide "B" dust	37	10	8.51	70.21	21.2	10	18	5	20	46.6	33.3	78.3	— 50	68.08
Calcium cyanide "A" dust	37	31	0	54.4	45.5	4	19	17	0	19.04	80.9	89.1	— 45.1	69.1
Check	29	11	5	67.5	27.5	50	0	18	20.58	52.90	26.4	—	—	—

Experiment 3, June 30.—Dusting for adults was done with a new model power duster. Nicotine dusts (1 and 2 per cent) at the rate of about 3 pounds per tree were used and the trees were very well coated with the material. The maximum and minimum temperatures for the day were 76°F. and 48°F., respectively. A good dust cloud was obtained. The dislodged insects were caught on a large canvas sheet spread beneath the treated trees. The creatures were placed in vials by means of a camel's hair brush and these containers left in the laboratory over night very loosely corked. Three vials were employed for the insects of each tree. The data secured are shown in Table 10.

TABLE 10.—CYANIDE DUSTING EXPERIMENTS IN THE McKAY ORCHARD.

VIAL NO.	MATERIAL	DOSAGE, POUNDS	DATE OF APPLICATION	DATE OF COUNT	NUMBER DEAD ADULTS	NUMBER LIVE ADULTS	PERCENTAGE KILL
1.	Lime-nicotine, 1 per cent	3	6–30	7–1	124	73	—
2	Lime-nicotine, 1 per cent	3	6–30	7–1	224	41	—
3	Lime-nicotine, 1 per cent	3	6–30	7–1	218	108	—
	Totals and average	—	—	—	566	222	71.82
4	Lime-nicotine, 2 per cent	3	6–30	7–1	126	12	—
5	Lime-nicotine, 2 per cent	3	6–30	7–1	190	9	—
6	Lime-nicotine, 2 per cent	3	6–30	7–1	132	14	—
	Totals and average	—	—	—	448	35	92.75
7	Lime-nicotine, 1 per cent	3	7–1	7–2	720	207	—
8	Lime-nicotine, 1 per cent	3	7–1	7–3	522	194	—
9	Lime-nicotine, 1 per cent	3	7–1	7–3	700	190	—
	Totals and average	—	—	—	1,942	591	76.66
10	Lime-nicotine, 2 per cent	3	7–1	7–2	670	68	—
11	Lime-nicotine, 2 per cent	3	7–1	7–2	347	6	—
12	Lime-nicotine, 2 per cent	3	7–1	7–3	591	32	—
	Totals and average	—	—	—	1,608	106	93.81

Experiment 4, July 1.—Dusting was similar in every way to that in the preceding experiment. The climatic conditions were much the same, the maximum and minimum temperatures for the day being 74°F. and 53°F., respectively.

The higher percentage of nicotine in the dusts showed a marked increase in the mortality of the insects (Table 10). The relation between the two amounts of nicotine used in each dusting and the percentage "kill" is proportionate.

Experiment 5, July 23.—Two trees were dusted with "B" grade calcium cyanide. About 2 pounds of dust were used per tree. The day was bright and fair, the maximum and minimum temperatures being 86°F. and 63°F., respectively. Counts were made from 15 spurs examined at the laboratory. The data secured are shown in Table 11.

TABLE 11.—CYANIDE DUSTING EXPERIMENTS IN THE MCKAY ORCHARD.

MATERIAL	DATE OF APPLICATION	DATE OF COUNT	NUMBER LIVE NYMPHS	PERCENTAGE SOFT-SHELLS	PERCENTAGE HARD-SHELLS	PERCENTAGE DEAD SOFT-SHELLS	PERCENTAGE DEAD HARD-SHELLS	PERCENTAGE DIFFERENCE FROM AVERAGE CHECK
Calcium cyanide "B" dust	7-23	7-24	80	43.7	56.2	23.9	10	46.3
Check	—	7-24	167	65.2	34.7	—	—	—
Calcium cyanide "C" dust	7-25	7-26	69	81.1	18.8	—	—	53.7
Calcium cyanide "A" dust	7-25	7-26	31	70.9	29.03	12	43	79.2
Check	—	7-26	251	55.7	44.2	—	—	—
Calcium cyanide "B" dust	7-29	8-1	91	39.5	60.43	—	—	39.1
Calcium cyanide "A" dust	7-29	7-29	17	64.7	35.2	75	81.8	88.6
Check	—	7-29	97	47.4	52.5	—	—	—
Lime-nicotine, 1 per cent	7-29	8-1	10	100	0	many	many	93.2
Lime-nicotine, 2 per cent	7-29	8-1	16	62.5	37.5	33.3	62.5	89.2
Check	—	8-2	82	59.7	40.2	—	—	—

Experiment 6, July 25.—Two trees were dusted with the small hand bellows duster, one being treated with "A" grade calcium cyanide and the other with "C" grade. A dosage of about 2 pounds was used and the applications made about noon. The day was fairly clear with clouds and sunshine. The maximum and minimum temperatures were 84°F. and 59°F., respectively, and a light breeze was stirring. Counts were made from 15 spurs of each tree which were taken to the laboratory for examination. The data are shown in Table 11.

Experiment 7, July 29.—Several trees were dusted with calcium cyanide and several with nicotine. The bellows duster was used

and about 2 pounds of material per tree applied. Operations began about 12 noon. The atmosphere was relatively clear, the maximum and minimum temperatures for the day being 90°F. and 64°F., respectively. Counts were made from 15 spurs at the laboratory. The results are shown in Table 11.

Comparing the number of nymphs on the dusted spurs with those on the check spurs leads to the assumption that some nymphs were killed by each dust application. "A" grade calcium cyanide ranks very close in toxic effects to 2 per cent nicotine dust. In the case of these dusts the hard-shells seemed to have been killed in greater numbers than the younger nymphs.

Experiment 8, Sept. 15.—The power duster was used to apply "A" and "B" grades calcium cyanide dusts and 2 per cent nicotine dust. The treatments were made about 11 a.m. The air was still and there were heavy clouds above. The temperature at the time of the experiment was 61°F., and the relative humidity 78 per cent. Sixteen trees were treated with each material from two sides. Before dusting 20 paper pie-plates were arranged on the ground beneath the selected trees to catch the dislodged insects. After the dust had settled the trees were shaken somewhat to displace, if possible, any psylla whose fall had been obstructed by leaves, branches, etc. The insects were counted as they were emptied into the revival boxes. One such box was used for the psyllas brought down by each material. The boxes were shaken gently in an effort to remove the dust materials, and as a rule, most of the dust did fall thru the spaces in the cloth. After this the boxes were set aside for a few hours. The revival count was made at 4:15 p. m. In order to determine what percentage of psyllas might have escaped death from the treatments, an examination of the lower branches of one tree of each plat was made. About seven minutes per tree were used in this observation. Table 12 gives the data obtained.

All the psylla brought down by "A" grade calcium cyanide were dead and but one live one was found on the branches after dusting. The small number appearing in the revival count was probably due to the escape of revived psyllas, as the boxes were not well covered.

Experiment 9, Sept. 16.—Calcium cyanide and lime-nicotine dusts were applied at about 2:30 p. m. It was cloudy and still. The temperature was 60°F., and the relative humidity 71 per cent. Ten trees were treated with each material and the dusting was done from two

TABLE 12.—CYANIDE DUSTING EXPERIMENTS IN THE MCKAY ORCHARD.

TREE NO.	MATERIAL	TREE DOSAGE, POUNDS	INSECTS DISLODGED, FIRST COUNT			COUNT AFTER FIVE HOURS		PERCENTAGE REVIVAL OF ADULTS	NUMBER ADULT ON BRANCHES AFTER DUSTING	
			Number adults	Number nymphs	Total number adults	Number adults dead	Number nymphs dead		Dead	Alive
1	Calcium cyanide "B" dust	1	29	3						
2	Calcium cyanide "B" dust	1	32	3	79	65	4	17.7	0	6
3	Calcium cyanide "B" dust	1	18	0						
1	Calcium cyanide "A" dust	1¼	14	1						
2	Calcium cyanide "A" dust	1¼	15	0	36	36	2	0	3	1
3	Calcium cyanide "A" dust	1¼	7	1						
1	Lime-nicotine, 2 per cent	1½	12	2						
2	Lime-nicotine, 2 per cent	1½	10	0	30	25	0	16.6	1	1
3	Lime-nicotine, 2 per cent	1½	8	0						

TABLE 13.—CYANIDE DUSTING EXPERIMENTS IN THE MCKAY ORCHARD.

TREE NO.	MATERIAL	TREE DOSAGE, POUNDS	INSECTS DISLODGED, FIRST COUNT			COUNT AFTER 24 HOURS		PERCENTAGE REVIVAL OF ADULTS	NUMBER ADULTS ON BRANCHES AFTER DUSTING	
			Number adults	Number nymphs	Total number adults	Number adults dead	Number nymphs dead		Dead	Alive
1	Calcium cyanide "B" dust	1⅕	28	1						
2	Calcium cyanide "B" dust	1⅕	39	1	89	86	1	3.37	18	5
3	Calcium cyanide "B" dust	1⅕	22	1						
1	Calcium cyanide "A" dust	1	69	1						
2	Calcium cyanide "A" dust	1	39	0	168	195	1	0	66	1
3	Calcium cyanide "A" dust	1	60	0						
1	Lime-nicotine, 2 per cent	2	89	0						
2	Lime-nicotine, 2 per cent	2	118	2	299	320	0	.92	66	1
3	Lime-nitocine, 2 per cent	2	92	6						

6-35

sides as before. Pie-plates were arranged beneath the selected trees to catch the dislodged psylla. The trees were jarred to get all possible insects on the plates before collection. A count of the insects was made as they were emptied into the revival boxes. The dusting materials were shaken out as well as possible and the boxes taken to the laboratory where a count was made after 24 hours. An examination of the lower branches on one tree of each plat was made about one-half hour after dusting. Seven minutes were allowed per tree. The temperature and relative humidity after the dusting were, respectively, 62°F. and 89 per cent. The data secured are shown in Table 13.

Both lime-nicotine and "A" grade calcium cyanide dusts showed a high percentage of toxicity. It will be noticed that twice as much nicotine as cyanide was used.

DUSTING IN THE MIDDLEWOOD ORCHARD

The next three dustings took place at the Middlewood orchard about 6 miles from Geneva. A rotary hand duster was used in each instance. Applications were made from all sides of the trees, and these were always well jarred before the insects were gathered up. The same type of revival box was used as described above. After remaining on the ground for an hour or so the revival boxes containing the psyllas were taken to the laboratory where they were left over night and counts made the next day. An effort was made to keep the boxes well covered with pieces of cheesecloth from the time the specimens were first placed in them until the revival count was made.

Experiment 1, Sept. 18.—Operations took place between 1:45 and 3:45 p. m. All grades of calcium cyanide dust and 2 per cent nicotine dust were used. The day was fair with clouds and sunshine. The temperature was 70°F., and the relative humidity 56 per cent. The falling psyllas were caught on cheesecloth sheets spread beneath the trees. An attempt was made to count the psylla after dusting. The insects were then placed in revival boxes which remained on the ground about two hours. During this time an examination was made of the lower branches on one tree per treatment. The insects in the revival boxes were counted the next day. Table 14 gives the data obtained.

The discrepancies in the first counts made in the field were presupposed, since it was a very difficult matter to count the specimens on cheesecloth under the prevailing conditions. The revival per-

TABLE 14.—CYANIDE DUSTING EXPERIMENTS IN THE MIDDLEWOOD ORCHARD.

TREE NO	MATERIAL	SIZE OF TREE	TREE DOSAGE, POUNDS	INSECTS DISLODGED, FIRST COUNT		COUNT AFTER 15 HOURS		PERCENTAGE REVIVAL OF ADULTS	NUMBER ADULTS ON BRANCHES AFTER DUSTING		PERCENTAGE ADULTS FOUND ALIVE
				Number adults	Number nymphs	Number adults dead	Number adults alive		Dead	Alive	
1	Calcium cyanide "C" dust	medium	1½	537	3	567	0	0	10	14	58.3
2	Calcium cyanide "A" dust	medium	1	858	2	1,055	0	0	28	4	12.5
1	Calcium cyanide "A" dust	large	1	241	5	245	1	0.4	37	1	2.63
2	Lime-nicotine, 2 per cent	medium	1½	133	—	107	3	2.72	7	6	4.61
1	Calcium cyanide "C" dust	medium	1½	57	—	40	?	—	—	70*	31.4†
2	Calcium cyanide "B" dust	medium	1½	344	—	350	35	9.09	—	168*	68.3†
3	Calcium cyanide "A" dust	medium	1½	749	—	717	106	12.8	—	72*	87.3†
4	Lime-nicotine, 2 per cent	medium	1½	212	—	179	5	—	—	93*	58.6†

*Numbers of adults brought down by redusting with nicotine.
†Percentage of reduction.

TABLE 15.—CYANIDE DUSTING EXPERIMENTS IN THE FINGAR ORCHARD.

TREE NO.	MATERIAL	SIZE OF TREE	TREE DOSAGE, POUNDS	DATE OF REVIVAL COUNT	REVIVAL COUNT OF ADULTS		PERCENTAGE KILL OF DISLODGED INSECTS	NUMBER OF ADULTS DISLODGED ON REDUSTING	PERCENTAGE OF REDUCTION
					Dead	Alive			
1	Calcium cyanide "B" dust	small	1½	8–26	2,013	0	100	481	80.7
2	Calcium cyanide "B" dust	medium	1½	8–27	1,855	0	100	132	93.3
3	Calcium cyanide "B" dust	small	1½	8–26	1,419	0	100	68	95.4
4	Calcium cyanide "A" dust	large	3⅓	8–26	2,679	0	100	351	88.4
5	Calcium cyanide "A" dust	medium	3⅓	8–27	1,193	0	100	206	85.2
6	Calcium cyanide "A" dust	large	3⅓	8–27	2,037	0	100	196	91.2
7	Lime-nicotine, 2 per cent	large	1¾	8–26	1,553	61	96.2	671	69.8
8	Lime-nicotine, 2 per cent	large	1¾	8–26	1,249	22	98.2	325	79.3
9	Lime-nicotine, 2 per cent	large	1¾	8–27	915	26	97.2	268	77.3

centages were therefore calculated from the counts made at the laboratory. Both dusts showed a total kill, but the proportion of live to dead insects on the tree dusted with calcium cyanide "C" grade was much higher than that on the other tree. It may be possible, too, that some psyllas escaped from the revival boxes, but this is not probable.

Experiment 2, Sept. 19.—A hand duster was used to treat two trees. Calcium cyanide "A" grade and lime-nicotine dust (2 per cent) were used. The temperature was 75°F., and the relative humidity 59 per cent. It was a clear day and but little air was moving. Forty pie-plates were arranged under each tree to catch falling psyllas. These remained on the plates about three minutes before being emptied into revival boxes which, after being covered, were left on the ground about an hour. During this time the regular examination of the lower branches of the trees took place. At the end of the experiment the temperature was 71°F., and the relative humidity 69 per cent. The data secured are shown in Table 14.

The "A" grade calcium cyanide dust gave the best results. It will be noticed that the dosage was less than that of the nicotine dust.

Experiment 3, Sept. 24.—Three grades of calcium cyanide dust and 2 per cent nicotine dust were applied between 1:40 and 3:30 p. m. The temperature at the beginning of the experiment was 62°F., and the relative humidity 58 per cent. It was clear and sunny and a light breeze was stirring. The "A" and "B" dusts were new, finely ground materials, while the "C" dust was the old coarse material. Forty pie-plates per tree were used to catch the dislodged insects which were allowed to remain about five minutes before collection. The specimens were placed in the revival boxes, where they remained about an hour before removal to the laboratory. Instead of the regular tree examination a redusting was made after the first psylla collection. The temperature at the end of the experiment was 60°F., and the relative humidity 58 per cent. Table 14 gives the data obtained

In counting the revivals, insects which showed any signs of life were called alive. Due to poor coverings while in the laboratory, it is very possible that there was some interchange of live insects of the several revival boxes "A" grade calcium cyanide dust showed by far the best control. The number of insects brought down was very great and the percentage of reduction high. It is quite possible that there was a contamination of both "A" and "B" revival boxes.

DUSTING IN THE FINGAR ORCHARD

The last few dusting experiments were carried on at the Peter Fingar orchard near North Germantown. A power duster was used and the same general methods followed as before. At this time of the year the leaves were beginning to turn and fall from the trees very easily. The flies had become quite inactive. The pie-plate method of collection was used in every case, and the trees were well jarred to bring down any adults which might have become entangled. The nicotine dust used was a commercial nicotine preparation containing about 2.7 per cent nicotine. At the end of the experiment the revival boxes were taken to the laboratory at Poughkeepsie where they were placed on the ground over night. It was endeavored to have the boxes as well covered as possible from the time of collection until the count.

Experiment 1, Oct. 25.—Several trees were treated with "A" and "B" grades of calcium cyanide dusts and with nicotine dust at about 3 p. m. The day was clear and sunny and a slight breeze was stirring The temperature was 66°F., and the relative humidity 51 per cent. Fifty pie-plates per tree were used, the insects remaining on the plates about five minutes before being emptied into the revival cages. The revival cages used here were wire test tube holders into which a piece of cheesecloth was placed to serve very much like a lining. The cloth was about 37 mesh to the inch. After the individuals had been placed in the cages, the latter were jarred to shake thru the dusting materials and then the loose ends of the cloth tied together over the top to form a covering to prevent the escape of any of the insects which might revive. The cages were allowed to rest on the ground about two hours before being taken to the laboratory. About 4:30 the trees were redusted, using "A" grade calcium cyanide at the rate of 3 pounds per tree. The humidity at the end of the experiment was much higher than at the beginning. Table 15 gives the data obtained.

The revival cages used in this particular experiment were not ideal. Because of the fine mesh of the cheesecloth and the hygroscopic properties of the calcium cyanide, it was impossible to remove the dust necessarily gathered with the insects. "A" grade calcium cyanide dust was more troublesome in this respect than any of the others, hence many of the insects were held in a small mass which consisted of part calcium cyanide and part psyllas. The insects, therefore, did

not have average conditions under which to revive. It is possible that many of the creatures brought down in the redusting and shaking had been killed by the first dusting. Both of the cyanide dusts seemed to have greater killing power and appeared to reach more of the insects than did the nicotine mixtures.

Experiment 2, Oct. 26.—Finely ground "A" grade calcium cyanide dust, coarse "B" grade calcium cyanide dust, and nicotine dust were used to treat several trees about 4 p. m. The sun was low and the atmosphere was slightly hazy, with a light breeze stirring. The temperature was 56°F., and the relative humidity 71 per cent. The revival boxes used in this instance were of the old type, four wooden sides with a cheesecloth bottom and this about 30-mesh to the inch. The insects were gathered from the plates about four minutes after dusting and were placed in the revival boxes which remained on the ground about one hour before being taken to the laboratory. Before and after dusting, examinations and counts were made of the lower limbs of one tree from each plat. The individuals in the boxes were counted the next morning. Table 16 giyes the data obtained.

The calcium cyanide dusts in almost every case showed a greater fall of psylla and a higher percentage of toxicity. It will be noted that "B" grade calcium cyanide used at a much smaller dosage than nicotine produced better results.

Experiment 3, Nov. 5.—Several trees were treated with "A" and "B" grades of calcium cyanide dust and with nicotine dust. The cyanide dusts were the old coarse materials. The temperature was 54.5°F., and the relative humidity 48 per cent. The atmosphere was slightly hazy and there were intermittent gusts of wind quite strong at times. Fifty pie-plates per tree were used and the psyllas were allowed to remain on these no longer than three minutes before collection. This was done to prevent the loss of specimens by wind. Counts of the psylla on the branches were made before and after dusting. The revival boxes remained on the ground about an hour before removal to the laboratory. Revival counts were made on the next day. Table 17 gives the data secured.

The thinning of foliage and the gusts of wind caused the dusts to be blown thru the trees rather than on them. Conditions were not at all satisfactory for a good cloud of dust, hence there was little chance that a concentration of gas could take place in the vicinity of the trees. Also, since the psylla were gathered from the plates almost immediately after the dusting, they were not long exposed to the

TABLE 16.—CYANIDE DUSTING EXPERIMENTS IN THE FINGAR ORCHARD.

TREE NO.	MATERIAL	SIZE OF TREE	TREE DOSAGE, POUNDS	REVIVAL COUNT OF ADULTS		PERCENTAGE REVIVAL OF ADULTS	APPROXIMATE NUMBER OF PSYLLA ON 200 SPURS			PERCENTAGE REDUCTION
				Dead	Alive		Before dusting	After dusting Dead	After dusting Alive	
1	Calcium cyanide "B" dust	small	1.6	742	0	0	75	7	3	96
2	Calcium cyanide "B" dust	large	1.6	2,532	8	0.31	122	27	1	99
3	Calcium cyanide "A" dust	large	2½	1,503	0	0	207	26	0	100
4	Calcium cyanide "A" dust	large	2½	1,241	0	0	61	37	0	100
5	Commercial nicotine dust 2.7 per cent	large	2½	612	51	7.3	117	1	4	96.7
6	Commercial nicotine dust 2.7 per cent	medium	2½	857	0	0	49	1	3	93.8

TABLE 17.—CYANIDE DUSTING EXPERIMENTS IN THE FINGAR ORCHARD.

TREE NO.	MATERIAL	SIZE OF TREE	TREE DOSAGE, POUNDS	REVIVAL COUNT OF ADULTS		PERCENTAGE REVIVAL OF ADULTS	APPROXIMATE NUMBER OF PSYLLA ON 200 SPURS			PERCENTAGE REDUCTION
				Dead	Alive		Before dusting	After dusting Dead	After dusting Alive	
1	Calcium cyanide "B" dust	medium	2½	139	36	20.5	242	0	14	94.2
2	Calcium cyanide "B" dust	large	2½	99	84	45.9	171	0	16	90.6
3	Calcium cyanide "A" dust	small	2½	50	21	29.5	335	0	31	90.7
4	Calcium cyanide "A" dust	large	2½	299	90	23.1	388	0	79	79.6
5	Commercial nicotine dust 2.7 per cent	small	2½	70	100	58.8	101	0	26	74.2
6	Commercial nicotine dust 2.7 per cent	large	2½	196	141	41.8	347	0	10	97.1

TABLE 18.—CYANIDE DUSTING EXPERIMENTS IN THE FINGAR ORCHARD.

TREE NO.	MATERIAL	SIZE OF TREE	TREE DOSAGE, POUNDS	REVIVAL COUNTS OF ADULTS		PERCENTAGE REVIVAL OF ADULTS	APPROXIMATE NUMBER OF PSYLLA ON 200 SPURS BEFORE DUSTING
				Dead	Alive		
1	Calcium cyanide "B" dust	medium	2½	68	90	56.9	1
2	Calcium cyanide "B" dust	large	2½	12	29	70.7	178
3	Calcium cyanide "A" dust	small	2½	36	168	82.3	147
4	Calcium cyanide "A" dust	medium	2½	12	114	90.4	161
5	Commercial nicotine dust 2.7 per cent	medium	2½	5	28	84.8	92
6	Commercial nicotine dust 2.7 per cent	small	2½	3	36	92.3	188

poison fumes. "A" grade calcium cyanide dust on the average showed the lowest percentage of revivals. The reduction percentages may not be strictly accurate because dusk came on before the counts could be finished and this might have caused some oversight of psyllas.

Experiment 4, Nov. 7.—At this time there were but few leaves on the trees and the dusting was held off until late in the afternoon because of the wind. Finely ground "A" grade calcium cyanide dust, coarse "B" grade calcium cyanide dust, and nicotine dust were applied. The temperature was 68.5°F., and the relative humidity was 51 per cent. Fifty plates were used per tree, and because of the hard wind, the insects were collected immediately after the dusting and emptied into the revival boxes. These rested on the ground but a few minutes before being taken to the laboratory. An examination and count of the psylla on the lower branches of the trees was made before dusting, but darkness prevented a second similar count. Revival observations were made at the laboratory on the next day. Table 18 gives the data obtained.

Dusting conditions in general were very unfavorable at the time of these applications. The treees had very few leaves so there was nothing to hold the dust in the trees. The psylla, because of the strong wind, were collected almost immediately after the treatment and thus were exposed only a very short time to the dust materials. "A" grade calcium cyanide dust produced the heaviest fall of psylla and stunned them for the instant. "B" grade calcium cyanide dust showed the highest percentage of kill of all the dusts.

TABLE 19.—COST OF MATERIALS USED IN CALCIUM CYANIDE DUSTING EXPERIMENTS IN 1924.

MATERIAL	COST PER POUND OR GALLON
Hydrated lime dust	$0.01
Calcium cyanide "C" dust	0.13
Calcium cyanide "B" dust	0.16
Calcium cyanide "A" dust	0.19
Calcium cyanide, lime, and Black Leaf 40	0.125
Nicotine, 1 per cent (home-mixed lime-nicotine dust)	0.0374
Nicotine, 2 per cent (home-mixed lime-nicotine dust)	0.0648
Nicotine, 2.7 per cent, Niagara A-1 dust	0.165
Lime-sulfur 1 to 8	0.0260
Lime-sulfur, lead, and Black Leaf 40	0.024
Lime-sulfur and Black Leaf 40	0.0191

COST OF MATERIALS

The approximate cost of materials used in these experiments is given in Table 19.

SUMMARY AND CONCLUSIONS

In the foregoing experiments weather conditions were not always favorable for obtaining accurate data. Winds often reduced the effectiveness of materials, and together with hard rains, probably occasioned the loss of many specimens. Reinfestation of the trees in the McKay orchard was bound to occur due to the flying habits of the adults and to the nearness of the respective plats.

Hydrated lime dust or calcium cyanide dusts did not appear to control the pear psylla in the egg or nymphal stages. A mixture of calcium cyanide, lime, and nicotine produced good results in several instances, but more evidence is needed to establish its value in this respect. The lime-sulfur spray at normal strengths containing lead and nicotine showed good control. It is very probable that the honey-dew surrounding the young nymphs acts, under certain circumstances at least, as a barrier to dust materials.

Under favorable conditions calcium cyanide dusts "A" and "B" grades and 2 per cent nicotine dust killed great numbers of the adults. The calcium cyanide dusts pound for pound appeared to be more toxic and more extensive in their effects than the lime-nicotine dust (2 per cent) or commercial nicotine dust.

Practically no injury resulted from cyanide dusts applied to mature foliage. Early in the season some burning was occasioned when the young leaves were treated with "A" grade calcium cyanide dust.

The best results from dusting with calcium cyanide dusts and nicotine dusts were obtained on calm days when the temperature was relatively high. It does not seem advisable to use calcium cyanide dusts when the temperature is below 55° F. Tho humidity is a factor of concern in the case of calcium cyanide dusts, it may be said that a direct relationship appears to exist between temperature and the effectiveness of the materials.

Two pounds of grade "B" calcium cyanide dust, at least 1½ pounds of grade "A" calcium cyanide dust, or 2 pounds of 2 per cent nicotine dust per average-sized tree are advisable for best results.

The foliage should always be dry before calcium cyanide is applied, and only thoro applications should be made.

A definite schedule for dusting cannot as yet be formulated, but the following suggestions are offered as giving promise of effective control. An application of a dust made on a warm, still day in February or March will serve to reduce the number of over-wintering adults, if the limbs and trunks of the trees are thoroly covered with the dust. A second application should be given when the majority of the individuals of the first generation are in the adult stage and while some hard-shells (about 25 per cent) are left. These stages of the insects may normally be expected in approximately 10 to 14 days after the petals fall. A third application should be made when all the insects are in the adult stage and before any eggs are laid. One dusting may be interpolated between the first and second applications, if desired. Should a later brood of hard-shells appear, they should be treated as suggested above for the first brood. A thoro dusting of the trunks and branches on a warm day in November may be found of considerable value in reducing the number of over-wintering adults.

It may be possible to reduce the amount of dust used in these experiments and still secure adequate control. The warmer and quieter the day, the less dust will be required. Too many growers, however, fail to secure satisfactory control with dusts because they do not use a sufficient amount of material and because they do not apply the dusts at the strategic time.

CHINCH BUG

In Florida, the chinch bug is not a pest of corn but is very injurious to St. Augustine grass, the most favorite lawn grass of the state. Mr. A. H. Beyer, of the Florida Agricultural Experiment Station, carried out experiments with Cyanogas Calcium Cyanide for the control of the chinch bug in 1923. His paper, Chinch Bug Control on St. Augustine Grass, was published in the Proceedings of the Florida

State Horticultural Society for 1924, pp. 216-219. The portion of his paper dealing with Cyanogas Calcium Cyanide is here reproduced. Further experiments by our own entomologists have indicated that better results may be obtained from several applications of Cyanogas Calcium Cyanide "A" Dust at the rate of 50 pounds per acre than from a single application of 150 pounds per acre (Fig. 5-6).

Fig. 5-6.—Dusting with Cyanogas "A" Dust for Chinch Bugs on St. Augustine Grass in Florida. Top of Can Punched with Holes for Dusting.

frequency of cloudy or wet weather during the hatching period of the young bugs. This dependency upon certain kinds of weather prevents these diseases from destroying the chinch bugs in large numbers. This disease attacks many other insects and is present every year throughout chinch bug territory. Therefore it becomes abundant under favorable weather conditions without artificial introduction. Another disease which has been found of value in chinch bug control during humid seasons, and which also attacks the cutworm and other insects, is *Sorospella uvella*.

Because of the fact that these fungous diseases are dependent on weather conditions, it is readily seen that their introduction in the control of chinch bugs is of little economic value.

Predators and Parasitic Enemies

Among these the most important enemies of chinch bugs are lady beetles, trash bugs, and the larvae of lace wing flies. Ants have also frequently been found to destroy chinch bugs. No true parasites have as yet been recorded by the writer as assailing the chinch bug.

Artificial Control Measures

Since the natural enemies of the chinch bug cannot be depended upon to hold it in check, it is obvious that those who wish to keep their lawns in flourishing condition must use artificial control measures to prevent injury by this pest.

The writer's introductory experiments in chinch bug control were conducted with the use of nicotine sulphate or tobacco dust, and also the introduction of tobacco stems to the lawn. Nicotine sulphate spray was applied at the rate of one part to 800 parts of water. In most cases these experiments were not found very effective because of the peculiar nature of the insect's feeding habits upon the grass attacked, as mentioned elsewhere in this paper.

The most effective results in control were obtained by the use of calcium cyanide, a newly produced chemical, which as shown from the writer's experiments, is about half as strong as sodium cyanide, a material which must be used in enclosures, such as the fumigation of greenhouses, flour mills, or tented fruit trees. The action of this chemical when applied under normal conditions of humidity and temperature, or when applied to moist soil, is the liberation of hydrocyanic acid gas in such quantities as to destroy all insects and rodents, the period required depending on temperature and moisture.

A series of experiments were conducted with calcium cyanide by sowing the dust broadcast over the lawn. Calcium cyanide is manufactured in three forms, flakes, granules, and powdered or dust. All of these forms were used in the experiments, but the most effective results were obtained by the use of the dust. This was sown broadcast over the lawn. Different applications were made, ranging at the rate of from 60 pounds to 200 pounds per acre. The dust was applied in the heat of the day when the lawns were perfectly dry. An inspection from 12 to 24 hours after the application of the dust showed that the most effective

results were produced by the application of the dust at the rate of 150 pounds per acre. In most cases where more than 150 pounds per acre was applied uniformly over the lawn injury by burning was experienced. The best safeguard found by the writer was the use of a little lighter application and a repetition of the experiment in about five days.

METHOD OF APPLYING THE DUST

The methods used in applying the dust with most satisfactory results were first, by means of the fan or blower duster. The bellows duster was not found to be so satisfactory because of its intermittent flow of dust. Another method which was found quite satisfactory was the use of a large can or bucket with a closely fitting cover which was punctured with a 6 or 8 penny nail to form a sifter top. By this ingenious device the dust can be sifted uniformly over the lawn. Under favorable conditions the most effective killing results were from 80 to 95 per cent of the chinch bugs.

The dust should be applied when there is as little wind as possible during the heat of the day, and the operator should be careful not to get his head directly over the container, or to breathe in the dust or fumes from the freshly opened cans. Where this precaution is observed there is very little danger. If one stands on the windward side of the container there is no danger in handling the material in the open air.

CALCIUM CYANIDE

Calcium cyanide is a substance having somewhat the appearance of slate. When exposed to moisture it gives off hydrocyanic acid gas, and where sufficient quantities are applied it is deadly to all forms of plant and animal life. When calcium cyanide is applied to a lawn there is no danger of the fumes of the hydrocyanic acid gas rising in sufficient quantities to be injurious to human life since it has about the same density as air.

Whenever the application of calcium cyanide is completed the duster or sifter used should be thoroughly cleaned, as when calcium cyanide unites with the moisture in the air a reaction takes place which corrodes the metal portion of the sifter or duster, and either effects the efficiency of their working or destroys them entirely by eating holes in the metal.

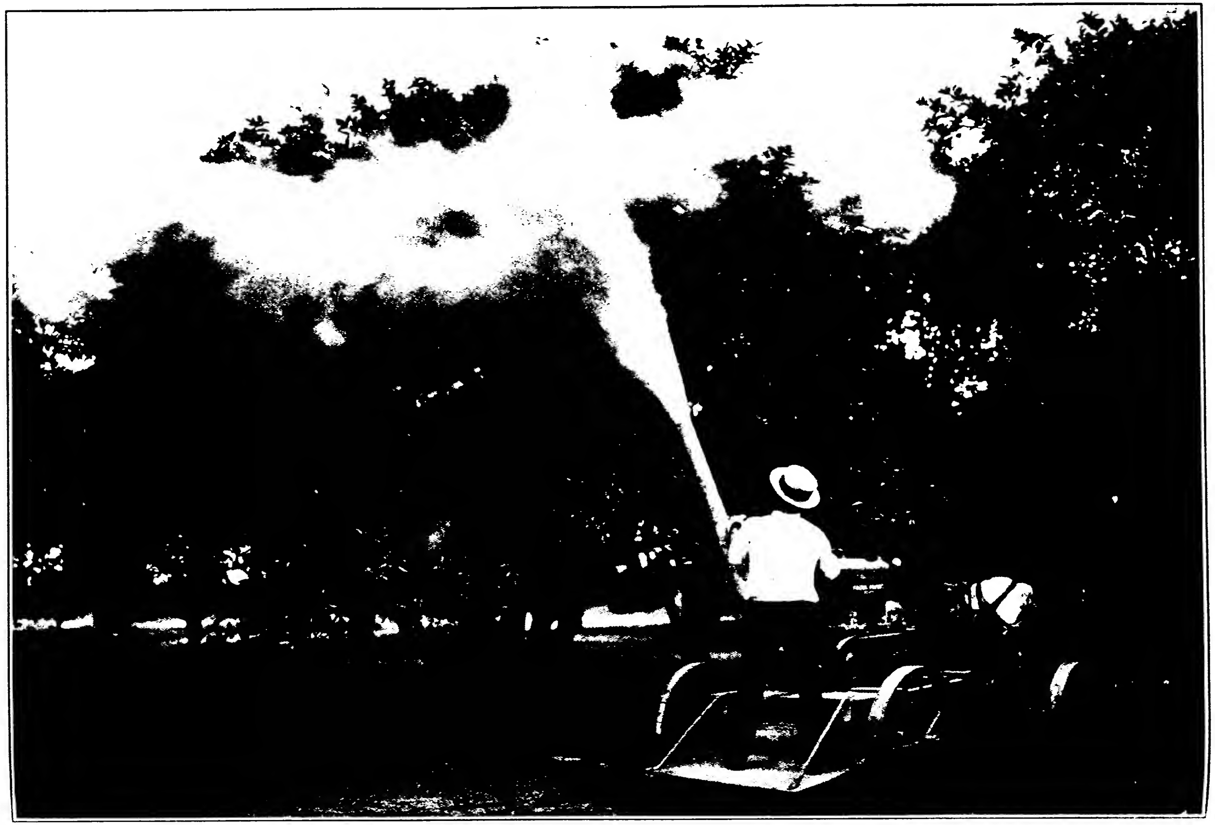

Fig. 6-6. Dusting Orange Trees for White Fly and Scale, Orlando, Fla. See Page 1-22.

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THE BRONZE-BEETLE.

ITS HABITS AND CONTROL AS AN ORCHARD PEST.

DAVID MILLER, Entomologist, Biological Laboratory, Wellington.

MOST of the insects injurious to orchard trees and fruit in New Zealand can be successfully held in subjection by the usual spraying practices. One of the few species that so far has evaded control is the bronze-beetle (Fig. 1). This insect occurs in most parts of the Dominion, but not in all districts is it outstanding as a detrimental factor in fruitgrowing. Where it has become a pest it is conspicuous mainly for its damage to developing apples, though several other plants are attached — *e.g.*, pear, plum, peach, gooseberry, black currant, raspberry, and blackberry.

Normally the bronze-beetle is a foliage-feeder, attacking the leaf in such a way that small shot-like holes are eaten through the lamina (Figs. 7 and 8). However, the chief damage is caused by the beetle eating patches from the epidermis and underlying tissue of developing fruit, mainly the apple, which, though not actually affecting the eating-quality as a rule, reduces the export value of the crop to a degree varying with the extent of damage to each individual apple.

FIG. 1. BRONZE-BEETLE. × 9.

[*Photo by E. B. Levy.*

The beetle attacks the apple most frequently in the vicinity of the stalk, or sometimes the stalk itself; and even the young bark at times is devoured from growing shoots. But the general surface of the apple is subject to attack, especially where clusters of fruit occur. Mr. J. H. Kidd, of Greytown,* states that when the bronze-beetle was excessively abundant one season the epidermis of the apple was not only eaten, but the fruit in many cases was devoured to the core.

Though the beetles may attack singly, it often happens that a number congregate at one spot, resulting in larger or smaller irregular areas of the apple-surface being damaged. In the case of very young fruit the smaller wounds may heal over (Fig. 3), leaving but little blemish on the mature fruit. Too frequently, however, the wounds do not heal over evenly, or, if they do, a scab-like patch of varying

* Mr Kidd has rendered most valuable assistance in the experiments to control bronze-beetle, and has also given important information based on his observations of this insect over a number of years. We are also indebted to him for placing his trees at our disposal for experimental purposes.

6-52

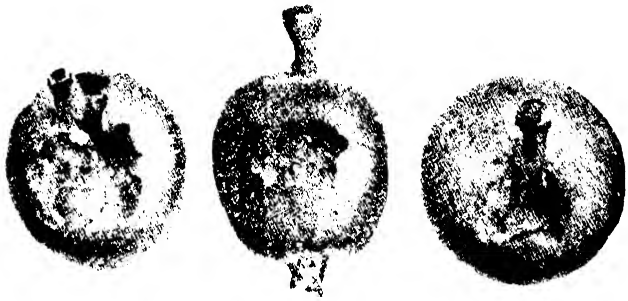

FIG. 2. YOUNG APPLES SHOWING CHARACTERISTIC DAMAGE BY BRONZE BEETLE.

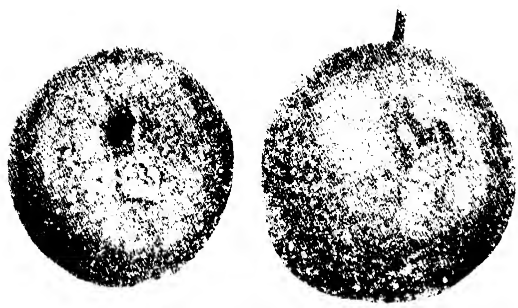

FIG. 3. YOUNG APPLES DAMAGED BY BRONZE-BEETLE, SHOWING THE WOUNDS HEALED.

FIG. 4. MATURE APPLE WITH WOUNDS CAUSED BY BRONZE-BEETLE HEALED OVER.

[*Photos by H. Drake.*

size remains on the surface. Another characteristic result of bronze-beetle injury is malformation. This may take the form of a small scabby nodule projecting from the surface of the apple at the point of damage, or the whole side of the fruit may grow out abnormally, destroying its symmetry (Figs. 5 and 6). In some cases pronounced fissures separate the nodules when the apple has been attacked at more than one place.

Regarding the varieties of apples attacked, there seems to be a considerable difference. At Greytown, Cox's Orange and Ribston Pippin were the most severely damaged, and Gravenstein slightly so, while Delicious and Sturmer were remarkably free of injury. The clustering of apples, as in the case of Cox's Orange, has probably a good deal to do with this variety being so severely attacked, since the beetles prefer sheltered locations while feeding. This point was especially noticeable at Greytown, the beetles being not only most abundant among clustering apples, but also on the leeward side of trees during strong winds.

Concerning the life-history of the bronze-beetle but little is as yet known. This insect, like the brown or chafer beetle (*Odontria zealandica*), is mostly active over a comparatively short period during November and December of each year. Mr. Kidd, during 1924, observed the first beetles on 26th October, but in the following season (1925) they were not noticed until the first week of November, reaching a maximum between the 20th and 30th of that month. During the first week of December, when the control experiments here recorded were carried out, the beetles, though past their maximum, were still extremely abundant. Toward the close of the year the numbers become less, and only a few are on the wing early in January.

Regarding the longevity of the beetles it is of interest to note that specimens captured on 4th December lived in the Laboratory until the 30th of the month. Thus the life of the beetle may extend over a period of about one month, giving some indication of what takes place under natural conditions.

A characteristic of the bronze-beetle is its flea-like leaping habit, and the ease with which it will drop to the ground when the trees are jarred. On returning to a tree the beetles very often move along the ground toward the bole before flying up.

There is no doubt that the larvæ live in the ground, feeding on plant-roots, though no larvæ have been as yet definitely located in the field. In one place where the beetles are particularly prevalent on the trees each year, larvæ, certainly of the same group to which the bronze-beetle belongs, were dug up from among grass-roots during June, but could not be reared to maturity. In the Laboratory, beetles have laid their eggs in soil, and larvæ have hatched out but died after a few days. In the field, beetles drop from the trees and bury themselves beneath particles of soil, but, though many were followed, no actual egg-laying was witnessed. Around the base of beetle-infested trees a great number of the insects are to be found thus buried.

CONTROL.

A factor that apparently has some effect in checking the bronze-beetle is cultivation of the orchard. This is borne out by the fact

that the larvæ live underground. Mr. Kidd found that when an orchard was uncultivated, so that grass and weeds covered the ground, the beetles were extremely abundant, and apples were eaten

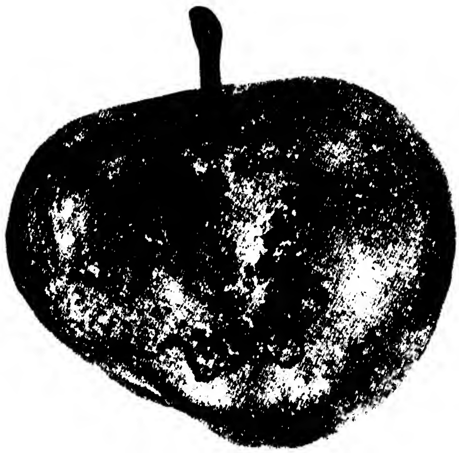

FIG. 5. MATURE APPLE SHOWING SCABBY APPEARANCE AND MALFORMATION RESULTING FROM BRONZE-BEETLE ATTACK ON IMMATURE FRUIT.

FIG. 6. MATURE APPLE SHOWING RESULT OF SEVERE DAMAGE BY BRONZE-BEETLE.

[*Photos by H. Drake.*

to the core as mentioned. Even gooseberries were so badly attacked that they had to be sorted after picking. Thorough cultivation was instituted, however, and each season, as the orchard became properly worked, the beetle infestation gradually lessened.

6-55

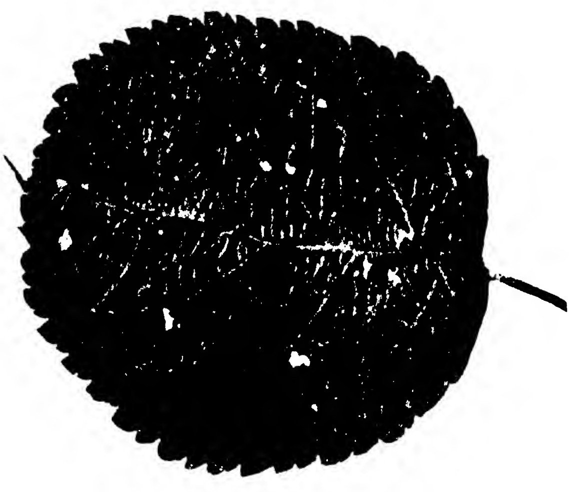

FIG. 7. APPLE-LEAF ATTACKED BY BRONZE-BEETLE.

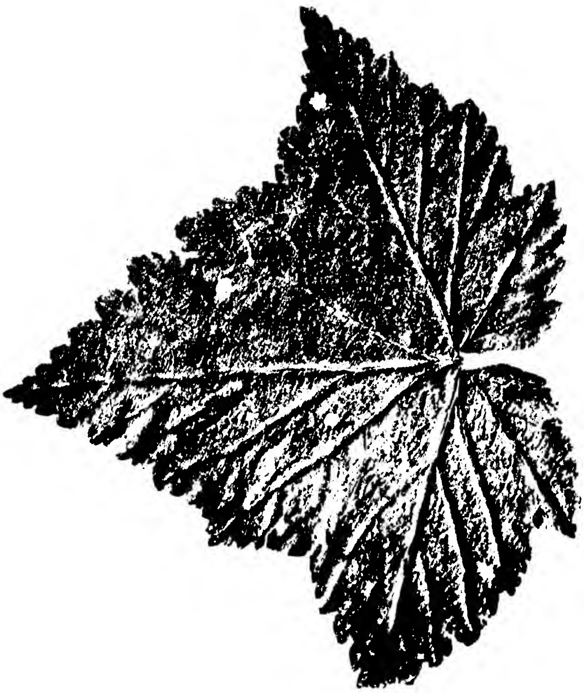

FIG. 8. BLACK-CURRANT LEAF SHOWING BRONZE-BEETLE ATTACK.

[Photos by H. Drake.

Regarding insecticides, since lead arsenate has so far proved ineffective as a satisfactory means of control, it was decided to try dusting with calcium-cyanide dust, "Cyanogas Calcium Cyanide A Dust," manufactured by the American Cyanamid Company, being used. Atmospheric moisture and the cyanide interact, resulting in the evolution of hydrocyanic-acid gas.

The dusting was carried out in the open air, the trees not being enclosed in tents. The weather conditions at the time were far from ideal on account of strong winds and intermittent showers; but the results of the experiments show that there is every possibility of dusting with cyanide being a means of controlling the beetle.

With the dust an equal quantity of air-slaked lime was mixed as a carrier. An amount of 1 lb. of cyanide was applied to each tree, the trees being 18 ft. apart both ways, and 10 ft. high. A large sheet of sacking was spread on the ground beneath each tree as it was treated, so that when the beetles fell they were easily observed.

The gas liberated from the cyanide caused the beetles to fall stupefied a few seconds after application, but it was found that though many died a considerable number recovered and returned to the tree. To overcome this, three-quarters of the cyanide was blown on the tree and the remainder on the ground immediately beneath. This proved effective, and the stupefied beetles on dropping were unable to recover, being killed by the gas liberated from the cyanide applied to the ground.

It was found that approximately 75 per cent. of the beetles on each tree treated were killed. To arrive at this percentage counts were made of the dead beetles on the sheet. These were then removed and the main limbs of the tree shaken, so that most of the living beetles remaining dropped, together with a number of dead ones which had not fallen during the application of the dust. The dead beetles were discarded and only the living counted, since it was found that a proportion of living beetles would still remain on each tree. The 75-per-cent. kill was remarkably constant for each experiment.

Under ideal conditions of calm weather there is no doubt that the percentage of control would have been much higher. Though the experiments were carried out under the lee of shelter-belts, there was sufficient wind to disperse a considerable portion of the dust. The weather had been showery, though the trees were dry at the time of dust application. The temperature was 66° F.

During the experiments it was found that the best results were secured when the dust was blown on to the apples, especially clusters, since it is there that the beetles mostly congregate.

Apart from the control of bronze-beetle, the experiments showed the possibilities of calcium-cyanide dust as a general insecticide. For example, the control of apple leaf hopper was very close to 100 per cent., as near as could be reckoned. These leaf-hoppers dropped dead immediately the dust was applied. The effect upon aphids was also very pronounced, but in this case the best results were secured when the dust came in actual contact with the insects.

Further experiments are being carried out and will be recorded in due course.

THE WEST INDIAN CANE FLY

The West Indian Cane Fly or Leafhopper, *Saccharosydne* (*Delphax*) *saccharivora* Westwood, is sometimes destructive to sugar cane in Haiti.

Dr. George N. Wolcott, Entomologist of the Service Technique, Port-au-Prince, Haiti, has conducted experiments with Cyanogas Calcium Cyanide for the control of this insect on sugar cane, and makes mention of this method in his as-yet-unpublished treatise "Entomologie d'Haiti."

Through the kindness of this author, we have been permitted to publish the following interesting account of this insect as well as the accompanying figure. (Fig. 7-6).

"*Saccharosydne saccharivora* Westwood is a beautiful light green Fulgorid with transparent wings, which sometimes occurs in such numbers on the underside of the leaves of sugar-cane as to be a pest of considerable importance. The first indication of infestation is that the leaves appear to be covered with a black crust. This is a sooty mold which grows on the deposit of a sweet sticky substance which the Fulgorids excrete in the form of fine droplets, which collects on the leaves below. As one walks through the cane, a cloud of minute flying green insects is noted, and by looking at the underside of infested leaves, one will see all stages of the insect.

"The adults have long transparent greenish wings, and the females at the posterior end of the abdomen have a mass of chalky white, fluffy substance like wax. She lays her eggs in clusters in the midribs of the leaves of cane, covering the wound with some of the fluffy substance. The minute greenish nymphs hatch in a few days, and as soon as they begin to grow, excrete more of this waxy white material, which collects in a long filament at the end of their body. They grow rapidly, sucking juice from the cane leaves, and if undisturbed, will transform to winged adults without moving from the leaf where they were born. The adults can fly, but ordinarily do not disperse far in a cane field until the originally infested leaves become too crowded, or unless disturbed. They tend to remain on the underside of the leaves, but on heavily infested young cane plants may entirely cover both sides of the leaves. If the infestation is thus severe, they may kill the cane, and even in nearly mature cane may cause considerable stunting.

"This insect is quite common in some sections of Haiti, while in Cuba and Porto Rico it is comparatively rare, as it

has numerous parasitic enemies. In Barbados, and especially in the dryer portions of Jamaica, it is sometimes a very serious pest. Up to a few years ago, control by means of insecticides was most unsatisfactory, as the insects on the under side of the leaves were hard to reach and kill by means of a spray, and those disturbed and flying away would only serve to spread the plague.

"Recently, with the development of calcium cyanide as an insecticide dust, control of this pest has become so simple that injury by it can always be prevented if a supply of the insecticide can be obtained within a reasonable time. The dust kills within a few minutes practically all the insects, both nymphs and adults, present on the plants dusted. A repetition of the dusting a week later will kill the young nymphs which have hatched from the eggs, as well as any insects missed by the first application of the calcium cyanide. The dust can most efficiently be applied by means of a dust gun, which indeed, is almost indispensible."

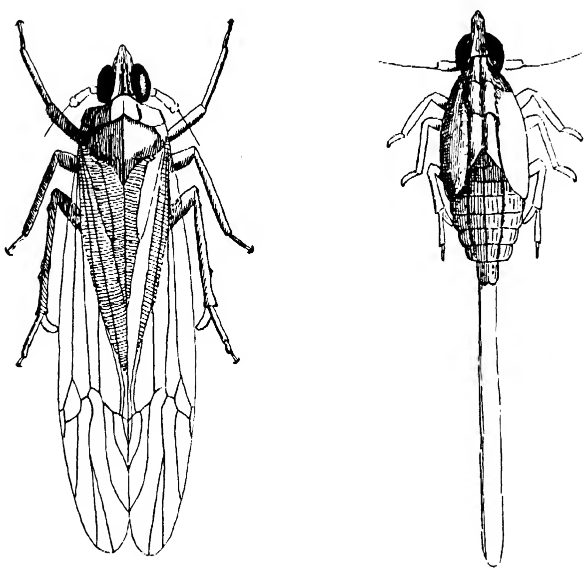

Fig. 7-6.—Adult and Nymph of *Saccharosydne saccharivora* Westw. (X15)
Plate used through courtesy of G. N. Wolcott.)

SUGAR CANE FROGHOPPER

The Sugar Cane Froghopper, *Tomaspis saccharina* Dist., is the scourge of the cane-growing industry on the Island of Trinidad, British West Indies. Although its present range is restricted to the West Indian Islands of Trinidad, Grenada, and St. Vincent, its ravages in Trinidad alone have been sufficient to occasion great concern among the growers.

At the beginning of the rainy season, in May or June, the first brood attacks the blades of the cane, causing them to dry up and die as if "blighted." When this brood has passed the canes throw out fresh leaves and resume growth once more. After an interval of two months, the cane is again set back by the attack of the second brood which is usually, but not always, of greater severity than the first. The third attack also occurs after a similar interval. The destructive effect of these successive attacks upon the development of the cane is very great and the yield is reduced to a considerable extent over the infested area.

In 1925, there were 6,583 acres of cane on the Island which were "blighted" by the Froghopper. The loss sustained was estimated at fully $1,000,000. These losses were so depressing to the industry in Trinidad that a special committee was appointed by the Governor of the Island to undertake investigations for the control of the Froghopper pest.

In 1925, tests for the control of this insect with Cyanogas Calcium Cyanide were instituted by Mr. F. W. Urich, Entomologist, and Mr. William Nowell, Director, of the Saint Clair Experiment Station, Port-of-Spain. It was found that Cyanogas was the only insecticide which would penetrate the froth surrounding the nymphs and effect their kill.

During 1926, further tests were advocated by Mr. Urich and Mr. Nowell, and were duly carried out. These tests proved that dusting with Cyanogas was an effective and practical method of control. An account of these experiments reprinted from the "Minutes and Proceedings of the Froghopper Investigation Committee," Part IV, pages 83 to 98, is here given.

Fig. 8-6.—Dusting Sugar Cane in Trinidad with Cyanogas Calcium Cyanide to Control the Froghopper.

A DUSTING TRIAL WITH "CYANOGAS" ON FROGHOPPER NYMPHS AT HARMONY HALL.

By R. Follett-Smith, B.Sc., A.R.C.S.

The trial was conducted on 30th and 31st August, 1926, by Messrs. McKinstry (Observer, Southern Section), Inniss (Harmony Hall Estate) and the writer, under the supervision of Mr. F. W. Urich. A method suggested by the Chairman of the Scientific Committee was employed.

Method.—Eighteen beds, 300 by 25 feet, approximately, one-sixth acre each belonging to field No. 4, Savannah, were selected. They had been planted on abandoned land in October, 1924, with BH 10 (12), across the beds, six plants in each row. The stools had been trashed, and the beds weeded and moulded, before the trial was commenced. Second brood nymphs were fairly abundant. The weather was fine and sunny, with a slight easterly breeze blowing. The soil was damp, but not wet.

The degree of froghopper infestation was measured by assigning marks to one stool in each row throughout each bed. The highest degree of infestation, as gauged by the amount of spittle present, was marked "5," and the lowest (complete absence of spittle), was marked "0." The selection of stools was made at random, the selected stools being denoted by knots tied in their leaves. Some forty stools in each bed were assessed, thus involving numerous, but, unbiassed and separate judgments. Each observer examined six beds, both before and after the dusting operation.

Alternate beds were dusted with "Cyanogas A. dust" (a powder containing 50 per cent. of calcium cyanide), applied round the base of every stool by estate labourers, using hand dusters. The amount of dust applied to any one stool depended on the amount of visible spittle. The time required for the complete dusting operation was 4½ hours, four dusters being continually in use.

After 18 hours, all the selected stools in each bed, both dusted and undusted, were again examined and marked. In the cases of certain beds, counts were again made by Mr. McKinstry after ten or seventeen days had elapsed from the day of the experiment.

Results.—It was noticed that spittle, on which the Cyanogas dust fell, usually collapsed and partly dried up, thus exposing the nymphs to the destructive effect of the liberated gas (hydrogen cyanide). Even when the spittle did not collapse, dead nymphs were frequently found within, thus demonstrating the high diffusing and penetrating power of the poison.

The numerical results obtained are expressed in the following table :—

TABLE OF RESULTS —(18th September)

Number of bed.	Treatment.	Number of stools assessed.	Percentage intensity of infestation * Before dusting.	Eighteen hours after dusting.		Up to 10 days after dusting.		Up to 17 days after dusting.		Percentage destruction. After 18 hours	After 10 days.	After 17 days.
				Dusted	Control.							
1	Dusted	53	61.6	20.8			—	11.0		66.2	—	82.1
2	Not dusted	42	58.1		61.9		—		44.7	—	—	—
3	Dusted	53	67.3	16.1		10.0		—		76.1	85.1	—
4	Not dusted	55	52.2		57.2		69.7	—		—	—	—
5	Dusted	52	48.6	4.8			—	6.5		90.1	—	86.6
6	Not dusted	46	49.4		57.1		—		76.7	—	—	—
7	Dusted	44	59.4	10.9			—	6.3		81.6	—	89.5
8	Not dusted	39	57.4		58.9		—		61.1	—	—	—
9	Dusted	55	34.6	7.7		8.5		—		77.8	75.5	—
10	Not dusted	51	22.6		28.4		61.5	—		—	—	—
11	Dusted	31	40.2	9.6			—	—		76.1	—	—
12	Not dusted	28	40.1		37.5		—	—		—	—	—
13	Dusted	34	58.2	2.4			—	—		95.9	—	—
14	Not dusted	43	58.1		61.0		—	—		—	—	—
15	Dusted	52	28.4	6.7		9.4		—		76.5	66.9	—
16	Not dusted	46	35.3		37.5		61.3	—		—	—	—
17	Dusted	48	40.3	1.0			—	—		97.5	—	—
18	Not dusted	39	41.0		44.1		—	—		—	—	—
	Total	811										
	Average		47.3	8.9	49.3	9.3	64.2	7.9	60.8	81.9	81.0	86.1

* NOTE.—" Percentage intensity " was calculated by multiplying the number of assessed stools in any one bed by 5 (the mark expressing highest possible degree of infestation), dividing by the sum total of marks representing the *actual* infestation and multiplying by 100.

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Conclusions—(1) The *average initial degree of infestation* per stool, was 47.3 per cent. of that of the most highly infected stools, being thus a medium figure.

(2) In the case of the majority of the control (undusted) beds, the percentage figure representing degree of infestation, had markedly *increased* during the 10 or 17 days interval that had elapsed from the date of dusting. This implies that eggs were continuously hatching throughout the period of the trial.

(3) The *degree of destruction* after 18 hours was relatively very high (average, 81.9 per cent.). It was maintained for 10 to 17 days (average, 81.0 and 86.1 per cent.), implying either (*a*) that no more eggs capable of hatching into froghopper nymphs were initially present in the dusted beds (which is contrary to what was found for the undusted beds), or (*b*) that the Cyanogas treatment had destroyed eggs as well as nymphs. This possibility will further be tested by special experiments.

Quantities and Costs.—The amount of Cyanogas powder used per acre was 30 lb., delivered from the " Cyanogas " hand duster. (The " Furet " duster was found to be more wasteful, delivering some 65 lb. of dust per acre for satisfactory results).

The price of Cyanogas powder in Trinidad is 25 cents per lb. hence cost per acre (30 by 25=$7.50).

The cost of labour (including supervision) was less than $1.00 per acre. Total, $8.50 per acre. (With more practice in applying the dust, and the employment of a diluted dust (using talc, powdered charcoal, or white clay as dilutant), the total cost might possibly be reduced to $6.00 or $7.00 per acre.)

20th September, 1926.

ENTOMOLOGICAL NOTE ON ABOVE.

At the time the dusting was carried out there was a predominance of nymphs and few adults were in the cane leaves. The nymphs were mostly in the 3rd and 4th stages and a small percentage was about to issue as adults. It was therefore the best time to dust. Another factor that made dusting more effective was that all small fissures in the ground and around the cane stools had closed owing to the prevailing moisture. It would have been better to have left the trash on the cane stalks as many of the dry leaves contained eggs which might have been affected by the gas; moulding up the canes might also have been omitted as it provided in some cases a hiding place for small nymphs which possibly the gas could not reach. A froghopper nymph shuns light as much as possible, but it also avoids excessive moisture. Most of the nymphs were on the cane stools and there were hardly any under the boucans.

30th September, 1926. **F. W. URICH.**

A DUSTING TRIAL WITH "CYANOGAS" AT CARONI ESTATE.

BY F. HARDY (Chairman, Scientific Committee).

In view of the successful use of "Cyanogas" dusting powder for destroying froghopper nymphs at Harmony Hall (*See* p. 83). a further trial was attempted on 20th September, 1926, at Caroni Estate. The following team conducted the actual counting— Messrs. Shand, Ross, and McKinstry (Official Observers under the Committee), Mr. Hinchy (Chemist, Caroni Estate), and Messrs. Follett-Smith and Hardy. Mr. Urich supervised the dusting operations. Mr. Grant (Manager, Caroni Estate), rendered valuable assistance throughout the whole trial, and Professors Ballou and Briton-Jones witnessed some of the proceedings. Mr. Arbuckle (Attorney, Caroni Estates, Ltd.), inspected the initiation of the work and its results.

Method.—Thirty-eight (38) beds, each 250 by 20 feet (approximately $\frac{1}{8}$ acre), belonging to field No. 86, Frederick, were selected. They had been planted in September, 1924, with D 109. The stools had been weeded two weeks before the experiment, but had not been clean-trashed. Second brood nymphs were fairly abundant, but not so abundant as they had been during the previous fortnight. The soil was fairly dry on the surface (contrast the Harmony Hall conditions). The weather was hot, dry and sunny.

Exactly the same method of counting was employed for assessing the degree of froghopper infestation, before and after dusting, as in the Harmony Hall trial previously reported. Alternate beds were dusted with "Cyanogas" by estate labourers, using "Cyanogas" hand dusters.

After 5 hours, some of the dusted beds were again assessed. Next day, another assessment, of a greater number of beds, both dusted and control (undusted), was made. After seven days, a final, complete assessment, was made. As far as possible, each observer assessed his own beds throughout. At the end of the trial, (28th September), the whole field of canes had practically succumbed to froghopper attack, and little second brood spittle was discernible.

Results.—The following table records the numerical data obtained.

TABLE OF RESULTS. CARONI DUSTING TRIAL.—(20th September).

Number of bed.	Treatment.	Number of stools assessed.	Percentage intensity of infestation.							Per Cent. Destruction.	
			Before dusting.	Five hours after dusting.		Twenty hours after dusting.		Eight days after dusting.		After twenty hours.	After eight days.
				Dusted.	Control.	Dusted.	Control.	Dusted.	Control.		
1	Dusted	49	48.5	3.2		4.7		8.0		90.4	83.5
2	Control	50	45.5		—		16.7		16.5		
3	Dusted	50	36.5	—		6.5		6.0		82.2	83.6
4	Control	50	41.5		—		30·5		25.0		
5	Dusted	50	54.0	—		15.1		7.5		72.0	86.1
6	Control	48	—		—		44.8		32.5		
7	Dusted	50	57.5	11.5		—		15.0		80.0	73.9
8	Control	50	43.0		—		—		19.5		
9	Dusted	43	49.4	5.2		—		6.6		89.5	86.6
10	Control	51	30.4		—		—		13.5		
11	Dusted	45	52.3	4.1		6.2		10.0		88.3	80.9
12	Control	57	58.3		—		41.8		36·0		
13	Dusted	50	26.0	—		5.5		6.5		78.9	75.0
14	Control	50	32.5		—		28.0		31.0		
15	Dusted	46	46.1	—		10.6		3.6		77.0	92.1
16	Control	48	—		—		38.6		7.6		
17	Dusted	50	44.5	17.0		—		13.5		61.8	69.8
18	Control	50	36.5		—		—		23.5		
19	Dusted	48	37.5	4.7		—		3.2		87.5	91.2
20	Control	49	25.5		—		—		7.6		
	Carried forward..										

TABLE OF RESULTS, CARONI DUSTING TRIAL.—(20th September).—*Continued.*

Number of bed.	Treatment.	Number of stools assessed.	Percentage intensity of infestation. Before dusting.	Five hours after dusting.		Twenty hours after dusting.		Eight days after dusting.		Per Cent. Destruction. After twenty hours.	After eight days.
				Dusted.	Control.	Dusted.	Control.	Dusted.	Control.		
	Brought forward..										
21	Dusted	50	49.5	—		7.1		7.5		85.6	84.8
22	Control	51	57.8		—		42.5		9.6		
23	Dusted	50	33.0	—		14.5		11.5		56.1	65.2
24	Control	50	38.5		—		32.0		39.0		
25	Dusted	49	53.2	—		14.3		4.4		73.1	91.7
26	Control	48	—		—		49.5		12.2		
27	Dusted	50	38.0	14.5		—		12.0		61.0	68.4
28	Control	50	41.5		—		—		18.0		
29	Dusted	48	28.1	2.1		—		3.8		92.5	86.5
30	Control	49	26.0		—		—		11.2		
31	Dusted	46	27.2	7.1		3.9		6.0		85.6	77.9
32	Control	47	27.1		—		25.8		8.8		
33	Dusted	42	22.0	1.8		3.8		4.5		82.8	79.9
34	Control	52	29.3		—		37.0		23.5		
35	Dusted	50	19.0	—		7.0		6.0		63.2	67.9
36	Control	50	19.0		—		19.0		26.0		
37	Dusted	42	20.2	—		3.5		3.1		82.6	84.6
38	Control	44	—		—		1.52		8.0		
	Total	1,852									
	Averages		38.1	7.1	—	7.9	32.2	7.3	19.9	78.5	80.0

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Conclusions.—(1) The average *initial degree of nymph infestation* per stool was 38.1 per cent. of that of the most highly infested stools, which is not particularly high, because—

(2) The nymph-infestation over the whole area was apparently waning at the commencement of and during the period of the trial, as indicated by the marked decrease in the figure representing the degree of infestation in the " control " beds at the various times when counts were made (38.1–32.2–19.9). (Contrast the Harmony Hall data, which showed that nymph infestation there was naturally *increasing* during the period of the trial.)

(3) The *degree of destruction* after 5 or 20 hours was relatively very high (average, 78.5 per cent.; compare the Harmony Hall figure, 81.9 per cent.). It increased slightly during the next 7 days (average, 80.0 per cent.). Whether or not froghopper eggs were also destroyed by the dusting still remains to be ascertained by further inspection of the beds during the next few weeks.

Quantities and Costs.—The quantity of " Cyanogas " powder used per acre was approximately 27 lb., delivered by the " Cyanogas " hand duster (contrast 30 lb. per acre in the Harmony Hall trial). Hence, cost per acre of material,=27 x 25c.=$6.75. Assuming cost of labour per acre to be $1.00, the total cost per acre was $7.75. This figure might considerably be reduced by using a diluted dust, and by further experience in dusting.

29th September, 1926.

A DUSTING TRIAL WITH "CYANOGAS" AT WATERLOO ESTATE.

By F. Hardy (Chairman, Scientific Committee).

A third field trial with "Cyanogas" dusting powder was carried out at Waterloo Estate on 22nd September, 1926. The following team performed the counting and recording ; Messrs. Ross and Shand (Official Observers), and Messrs. Follett-Smith and Hardy. Mr. McKinstry (Observer), helped in the dusting, and Mr. J. de Verteuil (representing Mr. Urich) supervised the dusting. Mr. Reid (Assistant Cultivation Manager, Waterloo Estate), rendered valuable assistance throughout, and inspected some of the beds after the dusting.

Method.—Twenty beds, each 200 by 20 feet (approx. $\frac{1}{11}$ acre), belonging to field No. 22, Waterloo, were selected. The cane stools had been weeded, and were trashed on the morning of the experiment. Second brood nymphs were very abundant, spittle being plentiful. The morning was rainy, and nothing, except the trashing, could be done until afternoon.

The same method of assessing the stools as regards intensity of froghopper infestation was practised as at Harmony Hall and at Caroni. Alternate beds were dusted by estate boys, using "Cyanogas" hand dusters. The effect of the dusting was assessed next day (23rd September), and again one week later (30th September) by the same team of recorders.

Results.—The numerical results obtained are recorded in the following table.

TABLE OF RESULTS, WATERLOO DUSTING TRIAL.—(22nd September).

Number of bed.	Treatment.	Number of stools assessed.	Percentage intensity of infestation. Before dusting.	Eighteen hours after dusting. Dusted.	Eighteen hours after dusting. Control.	Eight days after after dusting. Dusted.	Eight days after after dusting. Control.	Percentage Destruction. After eighteen hours.	Percentage Destruction. After eight days.
1	Dusted	48	59.0	10.0	—	9.1	—	83.1	84.6
2	Control	52	67.3	—	74.9	—	51.6		
3	Dusted	42	56.3	18.3	—	8.1	—	67.5	85.6
4	Control	51	56.6	—	52.9	—	38.4		
5	Dusted	50	66.8	15.0	—	4.8	—	77.5	92.8
6	Control	50	70.4	—	74.0	—	39.2	—	
7	Dusted	50	65.6	5.9	—	3.1	—	90.9	95.3
8	Control	50	63.7	—	67.0	—	37.5		
9	Dusted	46	65.2	12.7	—	5.6	—	80.5	91.4
10	Control	46	64.5	—	68.1	—	25.7		
11	Dusted	49	49.7	7.7	—	1.8	—	84.4	96.3
12	Control	53	61.7	—	57.3	—	34.7		
13	Dusted	50	77.2	9.2	—	1.6	—	88.0	97.8
14	Control	50	68.0	—	71.6	—	35.6		
15	Dusted	51	64.1	9.9	—	4.4	—	84.6	93.1
16	Control	53	59.1	—	66.3	—	38.5		
17	Dusted	50	59.0	(32.9)*	—	(10.8)*	—	(44.2)*	(81.7)*
18	Control	50	68.0	—	63.7	—	22.9		
19	Dusted	50	59.3	11.0	—	1.6	—	81.5	97.4
20	Control	50	55.7	—	51.3	—	29.2		
	Total	991	—	—	—	—	—	—	—
	Averages		62.8	11.1	64.7	4.4	36.7	82.4	92.9

* Only lightly dusted.

Conclusions.—(1) The average *initial degree of nymph infestation* per stool was 62.8 per cent. of that of the most highly infested stools which is relatively very high (contrast 38.1 per cent. at the Caroni trial and 47.3 at the Harmony Hall trial).

(2) Nymph infestation was nevertheless waning at the time of the trial, since the degree of infestation of the " control " beds had fallen off from 62.8 to 36.7 per cent. during the week which elapsed between the two recounts.

(3) The *degree of destruction* after 18 hours was high (82.4 per cent.), and increased noticeably during the next week (92.9 per cent.), These are the highest figures yet reached in our dusting trials.

Quantities and Costs.—The quantity of " Cyanogas " powder used was 48 lb. per acre. This, of course, is excessively high. Owing to the youthfulness of the dusting gang, much powder was wasted. In most instances, the amount of froghopper spittle was so great that considerable quantities of powder had to be expended to cover it. It was noticed in certain cases, however, that even when the spittle was not covered, the poison gas penetrated into it from adjacent dusted spittle. Furthermore, one bed (No. 17) was purposely only lightly dusted, say at the rate of some 10 lb. per acre. Here, the destruction was only 44.2 per cent. after 18 hours, but it increased to 81.7 per cent. in 8 days. These values are merely approximations, however, since they are derived from data relating to one bed only.

The total cost of dusting at the rate of 48 lb. of powder per acre, is about $13.00, which, of course, is prohibitive. Probably equally satisfactory results could be obtained at a much lower cost, by better supervision, greater care in dusting, older and more efficient labourers, and a diluted dust.

30th September, 1926.

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A NOTE ON THE RESULTS OF "CYANOGAS" DUSTING TRIALS FOR DESTROYING FROGHOPPER NYMPHS.

By F. HARDY (Chairman Scientific Committee).

The detailed results of the field trials with "Cyanogas" dusting powder on froghopper nymphs are recorded in three papers published in the "Proceedings," namely, (1) Harmony Hall Trial, by R. Follett-Smith. (2) Caroni Trial, by F. Hardy, (3) Waterloo Trial, by F. Hardy. The following table summarizes these results for comparison.

	Harmony Hall.	Caroni.	Waterloo.
Date of dusting	30th Aug.	20th Sept.	22nd Sept.
Period of trial	17 days	8 days	8 days.
Number and area of dusted beds	9 (1-6 acre) each	19 (1-9 acre) each	10 (1-11 acre) each.
Number and area of control beds	do.	do.	do.
Weather conditions	Fine	Fine	Cloudy.
Soil condition	Damp	Dry	Damp.
State of cane stools	Weeded, moulded and trashed	Weeded only	Weeded and trashed.
Intensity of infestation			
(*a*) at beginning of trial	47.3%	38.1%	62.8%
(*b*) at end of trial period (Control beds)	60.8%	19.9%	36.7%
Degree of destruction			
(*a*) a few hours after dusting	81.9%	78.5%	82.4%
(*b*) at end of trial period (Dusted beds)	86.1%	80.0%	92.9%
Quantity of "Cyanogas" powder used per acre	30 lb.	27 lb.	48 lb.
Approximate total cost per acre ("Cyanogas" at 25 cents per lb.)	$ 8.50	$ 7.75	$ 13.00

These results appear to warrant the following conclusions :—

(1) "Cyanogas" dusting powder is entirely satisfactory as an insecticide for froghopper nymphs in spittle.

(2) It is easily applied by ordinary estate labourers, with the usual estate supervision.

(3) It entails no equipment beyond hand dusters, which cost only $2.50 each.

(4) It is relatively harmless to operatives, provided reasonable precautions are taken.

(5) It seems not to be injurious to cane plants, if applied only to stem bases and adventitious roots.

(6) It rapidly decomposes (evolving poisonous hydrocyanic acid gas), and leaves only slaked lime as a residue in the soil.

(7) Its period of lethal activity is short (probably 4 or 6 hours in damp, not wet, soil).

(8) It can therefore produce no harmful after-effects.

(9) The cost of application is small.

(10) It is not bulky to handle.

On the other hand,

(1) "Cyanogas" powder is somewhat expensive (25 cents per lb. in Trinidad).

(2) It is liable to rapid deterioration if not carefully stored in air-tight containers.

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(3) " Cyanogas " hand dusters are somewhat flimsy in construction ; they need to be properly lubricated with graphite when in use, and thoroughly cleaned free from powder after use.

(4) Supervision of the dusting gang must be rigorous. At least one reliable driver to four dusters is required, particularly until the dusters gain proficiency.

(5) " Cyanogas " dusting powder destroys beneficial insects (predatory enemies) and small animals (lizards and frogs), as well as froghoppers, but only when it actually comes into contact with them, or falls in their immediate vicinity.

(6) It must be used with caution, even though not usually dangerous. The dusting operation should always be commenced at the windward side of a field or bed, so that the dust is not blown into the faces of the labourers as they progress. The hands should be washed after contact with the dust, and the antidotes recommended on the " Cyanogas " tins should be available in case of need during large-scale operations.

(7) Possibly, more than one dust-application may be necessary, particularly if the first application has not been accurately timed. Our field experiments, however, seem to indicate that the lethal effect of the dust is much more general and extensive than would be expected. There is some evidence that it destroys froghopper eggs as well as nymphs (*see* Harmony Hall results), but this point needs yet to be proved.

(8) It is usually believed that " Cyanogas " powder should be applied only when the soil is dry or but slightly moist. Our experience seems to indicate, however, that it is very effective even in soil that is quite moist (*see* the Waterloo results). It would probably be unwise to apply it during rain.

(9) The rate of application necessary in order to obtain the best results appears to be about 30 lb. per acre. This amount may possibly be considerably reduced by diluting the powder with some such substance as quick-lime, slaked-lime, talc, flour, dry powdered clay or powdered charcoal. Experiments are now being devised to test this possibility when third-breed nymphs appear. Mixtures of "Cyanogas" powder with such dilutents will be compared among themselves and with certain liquid insecticides during the next few weeks, employing the same method of counting as before.

1st October, 1926.

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A PRELIMINARY TRIAL WITH "CYANOGAS" POWDER AS INSECTICIDE FOR FROGHOPPER ADULTS.

By F. Hardy (Chairman, Scientific Committee).

At the suggestion of Mr. F. W. Urich, a trial of "Cyanogas" powder as means of destroying froghopper *adults* was made at Caroni Estate on the evening of 24th September, 1926, by Mr. R. Follett-Smith and the writer. The space between a row of ratoon canes and its adjacent rows was covered with "domestic" calico. Several stools were then dusted with "Cyanogas" powder from above, the operator standing on a chair. An ordinary "Cyanogas" duster was used. At the time of the experiment, adult froghoppers were not particularly abundant, but those that were in evidence were out on the upper ends of the cane leaves, or were in flight. After numerous attempts, a fairly dense cloud of dust was put up, and many of the adults were directly hit. Nevertheless, only 10 dead insects were counted after half-an-hour's effort. Possibly, many of the adults that had come into contact with the powder escaped without falling on to the calico. Nevertheless, the treatment appeared to be ineffectual as a practicable and adequate means of destroying froghopper adults, and was consequently abandoned. Even if it had been effective, the amount of powder required to destroy the insects would have been prohibitive, and the danger accompanying its use too great to favour it. Perhaps, the use of a diluted dust may have been just as effective and, at the same time, less wasteful, particularly if it had been applied with greater force as from an aeroplane in accordance with Dr. Withycombe's suggestion. As a field method, applicable under ordinary estate conditions, dusting with "Cyanogas" appears to have little to recommend it as an insecticide against froghopper adults. Its greatest value would seem to be exhibited when it is employed as a dusting powder on froghopper nymphs.

28th September, 1926.

Minutes and Proceedings of the Frogohpper Investigation Committee, Part IV. Issued October, 1926.

THE TEA "MOSQUITO"

The so-called Tea "Mosquito," *Helopeltis sp.*, is probably the most destructive insect pest of tea in India. It also occurs as a tea pest in Ceylon and the East Indies. In some localities, its depradations have been so serious as to occasion the suggestion of abandoning tea for another crop.

The Tea "Mosquito" is not in reality a mosquito, but a bug belonging to the Miridae (Capsidae), a family containing such well-known pernicious insect pests as the Garden Flea Hopper, *Halticus citri* Ashm.; the Tarnished Plant Bug, *Lygus pratensis* L.; the Apple Red Bug, *Lygidea mendax* Reut.; the Cotton Flea Hopper, *Psallus seriatus* Reut.; and others.

Previous methods of control, such as spraying and employing native labor in collecting *Helopeltis*, have not been effective. Pruning the tea bushes at the start of the infestation period and clearing up the types of vegetation which act as alternate hosts around the plantation have been helpful. The latter will, no doubt, have to be practiced in conjunction with the dusting, in order to insure against re-infestation of dusted areas.

We are reprinting the following article from the Planters Chronicle, Volume XXI, No. 32, August 7th, 1926, pages 527 to 531. In this paper are reported certain preliminary tests with Cyanogas Calcium Cyanide for the control of this insect in India.

Fig. 9-6.—Dusting Tea with Cyanogas in Ceylon.

PRELIMINARY REPORT
ON THE
APPLICATION OF CALCIUM CYANIDE DUST
TO THE
CONTROL OF HELOPELTIS IN TEA

BY

W. H. BRITTAIN, Ph D., M. Sc. (in Agriculture), ENTOMOLOGIST; and W. S. SHAW, Ph. D., M. Sc., A.I.C., TEA SCIENTIFIC OFFICER, U.P.A.S.I.

Introduction

The experiments described in this report are of a strictly preliminary character, and were conducted on a very small scale. The results are presented herewith not only on account of the great significance of the problem involved to the tea planters of South India and the necessity for the control of a pest responsible for so much damage, but also because of the promising nature of the results themselves, and because it represents the first attempt to control Helopeltis by this method.

Manufacture, Chemistry, and Reactions of Calcium Cyanide

In order to comprehend fully the nature of the results obtained it is essential to have some conception of the material employed in the experiments, especially with regard to the characteristic properties which make its use possible in tea culture.

Briefly, it may be stated that Calcium Cyanide is prepared by a series of processes commencing with Limestone, Coke and Nitrogen derived from the atmosphere. From the two former materials Calcium Carbide is prepared; which, after being raised to a white heat, is caused to absorb the Nitrogen, liberated from liquid air by boiling. The resulting substance formed is the well-known fertiliser Calcium Cyanamide. This Calcium Cyanamide is then fused with a Sodium Chloride in an electric furnace, by which process the Cyanamide takes up one more atom of Carbon and is thus converted into Calcium Cyanide, a substance with profoundly different chemical characteristics from Cyanamide.

When Calcium Cyanide is acted upon by the water vapour present in the atmosphere, gaseous Hydrocyanic acid (Prussic acid) is produced, the reaction involved in the production of this acid being explained by the following equation :—

$$Ca(CN)_2 + 2H_2O = Ca(OH)_2 + 2HCN.$$

The rapidity with which this hydrolysis takes place is dependent mainly on three factors :

1. The thinness of the layer of Cyanide.
2. The size of the particle.
3. The relative humidity.

The result is that a number of grades of the cyanide material are in existence, the commonest form appearing in the market being that termed commercially as 'Cyanogas "A" Dust.' This 'A' Dust is a very fine, slate-coloured powder, of which 80 per cent will pass through a 200 mesh sieve. Using this grade, it has been determined that, when the material is spread out in a thin layer such as is formed when it is projected from an appropriate dusting machine, 90 to 98 per cent of the poisonous hydrocyanic acid gas is evolved within the first two hours, provided that the relative humidity is 35 per cent or more. If the relative humidity is below 30 per cent the evolution of the gas is considerably retarded. I

may be added that localities with such a low humidity as 30 per cent are more the exception than the rule in tea growing districts. The maximum concentration of the gas is attained after a period of about forty minutes, but there is very little increase after the first five minutes exposure to the suitable moisture requirement. Further, it has been determined that the reaction takes place practically independently of the temperature. Coarser grades than the 'A' Dust are produced for certain special purposes, but where these are used, or where the thickness of any one of these grades is increased, the evolution of the gas is correspondingly slower.

Advantages claimed for Calcium Cyanide

It is claimed for Calcium Cyanide, that it has the highest range of adaptability of any other known insecticide. Arsenical or other food poisons may be effective for insects that eat solid food, while oil emulsions and other contact poisons may destroy insects of the suckling variety that sting the plant and feed upon the liquid sap of the latter. It has been shown by Andrews that the Helopeltis insect has the peculiar power of dealing with contact poisons, by systematically washing itself free from the insecticidal liquid. It was therefore concluded that spraying was of little avail against the pest; however, owing to the patent powers of Calcium cyanide as an insecticide, without the necessity of contact with the insect, it was felt that it might prove of some avail in assisting, if not completely eradicating, the pest. In support of this, it may be added that Calcium Cyanide is mainly utilized as a controlling agent for insects of the sucking type, to which type Helopeltis belongs and some examples of its application to such insects which might be cited are, the elimination of plant lice, plant bugs, thrips, psyllas, fleas, etc. It may also be employed satisfactorily against certain species of leaf beetles and other insects of the biting type. These instances given by no means exhaust the application of Calcium Cyanide as a control against pests, but a discussion of all the uses of the material is outside the scope of the present article.

A further advantage of the material is the ease with which it may be transported from place to place: but possibly the greatest advantage, and one which will appeal to the South Indian planter, is due to the fact that no water is required for the application of the dust. It is a well-known fact that one of the greatest difficulties experienced by planters in their attempt to control insect or blight attacks by means of sprays is due to the inadequacy of their water supply. In the case of Calcium Cyanide no preliminary preparation of the material is required, no water has to be carried to the place of operations, the material can be applied with comparative ease and rapidity, the effectiveness of an operator equipped with a duster is approximately five times as great as one using a sprayer and finally the equipment employed is simpler, lighter, and less expensive.

A possible argument against its use in Tea may be based on the fact that Calcium Cyanide is a deadly poison. Though it must be said, before proceeding, that further work must be done with regard to any residual poisonous effects of the material, still there is sufficient theoretical and practical evidence to indicate that there is no poisonous deposit left on the leaves after a short period of time. As has already been explained in a previous paragraph, all the poison has been evolved in the form of a gas leaving behind harmless Calcium Hydroxide (Hydrated Lime). To illustrate the fact of the complete loss of poisonous residue, the leaves of a tea bush treated the previous day have been repeatedly eaten without any harmful results. While it is not pleasant to have the material blowing directly into

one's face, this unpleasantness can be largely avoided by proper manipulation; and in the many experiments which have been conducted with this material in other spheres besides tea, no coolie has ever suffered injury. Thus no fatal accident has ever been reported from any country where the material is used on a very large scale.

With reference to the poisonous effects of Calcium Cyanide on mammals, it has been stated in the *Journal of Hygiene* (Vol XXI, No. 3, May 1923) that 'it requires a concentration of 8 parts of Hydrocyanic gas in 100,000 parts of air to kill a dog in half an hour; cats die from twelve parts and goats and monkeys from twenty-five, and it may be assumed that a man will require as much as a goat or a monkey.' A man becomes unconscious only when exposed to a high concentration, and if the concentration that caused unconsciousness is not increased, a comparatively long latent period intervenes before death. A person who becomes unconscious owing to exposure to moderate concentrations of Hydrocyanic gas recovers rapidly when placed in the open air.

If, therefore, 100 pounds of the straight product were used per acre this would yield twenty-six pounds of Hydrocyanic acid gas, and assuming that the whole acre were roofed over to a height of six feet and further that all the gas were given off at once, this would give a concentration within the enclosed area of 132 parts of hydrocyanic acid gas per 100,000 parts of air, or 66 parts, if the 50 per cent dust is used. However, not more than a third of the concentration is attained at any one time, even in tents, so that even in enclosed spaces the most that could be attained would be 22. In the open air it is clear that even this concentration of 22 could not possibly be obtained under the conditions specified of 100 pounds of material to the acre, and hence it is almost a practical impossibility to obtain anything approaching a fatal dose while operating in the open air. Practical proof of this is afforded by the fact that one of us has been using the material constantly for a year and has often been enveloped in clouds of the dust, without any disagreeable consequences being experienced. Short of having the material administered in food, there appears to be no possibility of harmful results accruing from the use of the material in the open air, but it is advisable to understand the simple precautions given on the containers thoroughly, and to follow these as closely as possible throughout the operations. It is further stated that constant dusting by one coolie may result in a slight headache, and it is therefore recommended that a coolie should do one half a day's dusting and then be relieved by another coolie.

Experiments with Helopeltis

The estate on which the following experiments were conducted is situated about four miles from Vandiperiyar, in Travancore. The bushes were in their second year from pruning and though in quite good condition, plucking had had to be postponed for a number of weeks owing to the ravages of Helopeltis.

The first test performed was made on a clump of Helopeltis insects which had been caught by children previously. This clump consisted mainly of adult insects, but also contained a number of 'nymphs' or larvæ. On to this clump a small whiff of the material was blown, and within a second most of the insects were killed. Even those insects which were in the middle of the clump, and had thus escaped contact with the dust, had also been killed. From this test it was clear that the material was extremely toxic to the insects and the way was clear for field experiments.

The tests in the field were made at between three and four in the afternoon and between eight and nine in the morning. In both instances there was a fresh to heavy breeze blowing throughout the progress of the work; and further, in both cases rain fell both previous to and during the operations. Usually conditions of rain and heavy wind are not conducive to the best results in any dusting operation, but as will be seen later these factors did not diminish the degree of effectiveness to any appreciable extent.

The exact infestation per bush could not be accurately determined, even though extreme care was taken in the examination of the bushes for insects It would appear, however, that the infestation was at least equivalent to five insects per bush. These five insects were usually found in the proportion of three adults to two larvæ. In order to increase the number of insects per bush for purposes of experiment, four more insects, which had been previously collected by children, were added to each bush.

In the first day's tests, both the 'A' dust and the 'Dusting mixture' were used, the latter dust consisting of 'A' dust, diluted with an equal quantity of superfine Sulphur, and which is especially efficacious against Red Spider. Owing to the prevailing heavy wind it was found necessary to make use of a 'Cloth trailer', under which the dust was projected. As no canvas was available a piece of ordinary factory cloth (cotton) 6feet wide and 20 feet long was used. This was attached in front to a light bamboo pole. A man stood in front and manipulated the sheet so as to permit of the least loss of the dust, while behind him stood the man with the dusting machine, who pumped the dust under the sheet in such a way as to secure the best possible distribution of the dust, and it was found advisable to have a further coolie assisting in the manipulation of the sheet behind. Rather a heavy application was given as it was felt that it would be easy to reduced the amount used in later experiments, provided the initial experiments were successful.

At the outset the difficulty presented itself of finding a simple, speedy, and accurate method of checking the results. As the greater part of the dead insects fall from the leaves either on to the ground or into the middle of the bush, where they cannot be found; it was decided to base our results on the number of living insects found on a number of treated bushes as compared to the number of insects found on the same number of untreated bushes. Children employed on the estate for catching Helopeltis, and hence thoroughly experienced in finding the insects, were used in the experiments. As a matter of interest it was decided to test the ability of these children in finding the insects on the bushes. Forty-eight bushes were therefore selected, four insects were added to them, so that there were at least 192 insects over the area under consideration. To this number must be added the number already present in the bushes. The children were then sent into the 48 bushes and instructed to collect as many insects as possible. The result of the first finding was only 74 insects; they were then required to repeat the find and returned after a second and third attempt with an extra 26 and 19 insects respectively per attempt. This gave a total number of insects found as 191 or 62 per cent of the number of insects actually added to the bushes.

In the following table, giving the details of the results secured, only the living insects found are recorded, for it will be understood that it was only possible to find a very small percentage of the numbers killed, for reasons already given. The table is as follows:—

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No	Treatment	No. of lbs. per acre.	No. of bushes involved	Temperature		Relative Humidity.	No. of insects alive after treatment	
				Wet Bulb	Dry Bulb.		Larvæ	Adults
1.	'A' Dust ...	111	53	73	73	100	1	0
2.	'S' Dust ...	110	44	75	75	100	0	4
3.	Control ...	Nil	48	...	...	...	119 insects alive including adults and larvæ.	
4.	Control ...	Nil	43	68	68	100	28	20
5.	'A' Dust ..	100	120	68	68	100	0	0
6.	Control ...	Nil	30	...	...	...	13	30

Discussion of Results

Though the methods employed in checking these results were of necessity rather crude, the evidence of large numbers of live Helopeltis individuals on the controls, as compared with the practical freedom of the treated bushes from them, indicates definitely that the material has a particularly high toxicity towards the particular insect under discussion. It would appear that the 'S' Dust is rather less effective in killing the insect, but it must be borne in mind that this 'S' Dust has only half the poisonous composition of the 'A' Dust, and in the experiments carried out less of the 'S' Dust was used per acre.

Conclusions

In these preliminary tests one important point has been demonstrated in a very clear manner, viz., the extreme toxicity of Calcium Cyanide to Helopeltis. Without undue optimism we can regard this fact as distinctly promising. However, when one remembers the successive failures which have accompanied any attempts to control Helopeltis, it is advisable to hestitate before making definite recommendations based on incomplete evidence. Thus, before advocating the use of Calcium Cyanide for the control of Helopeltis on tea estates under practical conditions, other important points must be subjected to rigid scientific and practical study. The following are some of the most important:

1. The whole economics of the situation, including a standard method for accurately expressing the degree of infestation, the determination of the actual reduction in yield of leaf following upon the different degrees of infestation; and (provided control experiments are successful) the minimum degree of infestation that will justify the adoption of such control measures.
2. The minimum dosage required per acre.
3. The minimum number of applications required and the intervals between such applications. This point is important, as it must deal with the insects hatched after the previous application of the insecticide.
4. The effect of dusting with and without a trailer; the best type of trailer to use and the most advantageous method of manipulation.
5. The dilution of the dust which will give the best results, i.e., whether it would be better to use a certain quantity of undiluted material or whether better results would be obtained by the use of a smaller quantity diluted to some appropriate extent with some convenient 'filler.'
6. The effect of other food plants and habitats of Helopeltis on an infestation.
7. The burning effect of the free hydrated lime remaining after the liberation of the hydrocyanic gas: This effect was noted during the experiments already described, and found to be nil; but this observation can hardly be claimed as conclusive owing to the fact that as periods of heavy rain were experienced after the application, it is more than possible that the hydrated lime was slaked at too rapid a rate to have any caustic effect, and it is further possible that a large percentage of the lime was washed away by the heavy rains.

It will be clear from the foregoing points that much work has still to be done with reference to the use of Calcium Cyanide as a controlling factor for Helopeltis; but it is hoped that all the points already mentioned, together with many others, will be made the subject matter of careful study at the earliest possible opportunity.

Issued November 30, 1926.

[*EXTRACT.*]

DUSTING WITH CALCIUM CYANIDE FOR BANANA THRIPS CONTROL.

BY JOHN L. FROGGATT, B.Sc.

As a result of earlier observations made on the life history and control of the banana thrips (*Anaphothrips signipennis* Bagnall) dusting with sulphur and pyrethrum powder was recommended for its control. Further study of the control aspect of the problem, however, led to preliminary trials with other materials, included amongst which was calcium cyanide; these tests, indicated that with this latter chemical quicker and more certain results could be obtained than was the case with either of the two previously recommended.

The preliminary trials with calcium cyanide were made in the Gympie area in April, 1926, and in the Innisfail area in May of the same year. The results were so promising that field trials were laid down in the latter district towards the end of October, 1926.

HABITS OF THE THRIPS.

Before dealing with the details of the field trials, it may be advisable to give a brief resumé of the habits of this insect, as they bear directly on the scheme of control work laid down.

The eggs are deposited in the plant tissue, and the larvæ on emerging form colonies with some of the adults; these colonies are found both on the pseudostem under the leaf-sheaths, and on the fruit in the bunches, especially in the base of the hands. The larvæ when full fed travel down into the soil where they pass through the pupal (or chrysalis) stage; the adults, after emerging, crawl back on to the plant to carry on the next generation.

LETHAL ACTION OF CALCIUM CYANIDE.

On exposure to air, calcium cyanide gives off hydrocyanic or prussic acid gas which acts extremely rapidly and is very deadly to the thrips. The preliminary trials showed that a light cloud of the dust on an exposed colony of thrips will destroy every individual comprised in it within five to ten seconds, and if the dust be blown lightly upwards under the opening bracts on a young bunch, four to five seconds will suffice to kill every thrip present under the bract, or in a young hand of fruit.

FIELD TRIALS TO DETERMINE THE PRACTICABILITY OF DUSTING ON A PLANTATION SCALE.

Two trial plots were laid down in different parts of the Innisfail district; the arrangement being the same in each case. In the first plot the stools were over two years old and were carrying a considerable amount of fruit; in the second plot, the stools had, for the most part, not thrown their first bunches.

Each plot was divided into three sections of fifty stools arranged in five rows of ten stools, with two rows of ten stools between the sections to act as check rows.

In plot 1 the area had not been chipped for some time, although spraying the weeds with arsenic solution had been done. In plot 2 the area had been recently chipped, and was again chipped on 26th October. The differences in cultivation accounted, in part at least, for certain differences in results obtained in the two plots.

Climatic conditions over the period of the trials were hot and dry until 16th November, when muggy, showery conditions prevailed until the 23rd November.

The dusts used in the preliminary trials were calcium cyanide "A" and "B" dusts, the latter containing sulphur, but as the "B" dust showed no advantage over the "A" dust in these early small scale trials, it was not included in the field trials in October. The stems and bunches were dusted with calcium cyanide, but, in order to determine the action, if any, of soil treatment on the soil-frequenting stage, the trials were extended to include soil fumigation; calcium cyanide flakes and paradichlorobenzene were tested for that purpose.

When the trials were instituted in October thrips were fairly numerous and showed a marked increase in numbers in the first fortnight of November.

On plot 1 treatments were given on the 21st and 29th October and on the 8th November, and the final examination was made on the 17th November. On plot 2 treatments were given on the 26th October and on 2nd and 12th November, and the final examination was made on 19th November.

DETAILS OF TREATMENT.

In all sections of the two plots, the stems and bunches were dusted with the "A" dust, one pound doing about two hundred and fifty stools; in addition to the dusting of stems and bunches, soil treatments were applied in two sections, as follows:—

In section 1 of each plot, half an ounce of calcium cyanide flakes was buried in the soil at a depth of 3 to 4 in., and about 6 in. out from the base of the plant. In section 2 no soil treatment was used. In section 3, half an ounce of paradichlorobenzene was buried in the soil at a depth of 3 to 4 in. and about 6 in. out from the base of the plant.

The soil treatment was carried out by digging two or more holes to the required depth round the plant, and distributing the dose between them; the holes were then filled in, and the soil pressed down with the foot.

Dusting was carried out with a hand bulb-blower, the rubber bulb being about $4\frac{1}{2}$ in. in maximum diameter, and the neck being fitted with a rubber stopper through which projected a length of copper tubing about 6 in. long and $\frac{3}{16}$ in. in diameter. In operation the neck of the bulb is held in one hand to obtain direction of the blast, while the bulb is rotated and pressed with the other hand; in this way a steady stream

of dust can be maintained, and directed as desired. When dusting the stem each lower leaf-sheath was drawn slightly away so as to permit of the dust being blown well down towards the base, and then let return to its original position.

Only a dust-cloud should be blown onto the plants and fruit; if proper care is not exercised and a coating of powder is left on the fruit, scalding will result due to the quicklime produced by the chemical decomposition of the calcium cyanide as expressed in the following formula:—

Calcium cyanide + water yields quicklime + "prussic" acid

$$Ca(CN)_2 \quad + \quad H_2O = CaO \quad + \quad 2HCN.$$

The results obtained in both plots were very similar but were rather more striking in plot 2 than in plot 1. The final examination of both plots showed that in section 1 only an odd small colony was noted and the number of thrips present was very low. In section 2 only an odd small colony was observed, although the number of thrips present was somewhat higher than was met with in sections 1 and 3. In sections 3 only an odd small colony was present and the number of thrips, although slightly higher than in section 1, was comparatively low. In no case in any of the treated sections were thrips generally numerous. In the untreated check rows, colonies, often large, were found on practically every stool and bunch, and the number of thrips present was high.

It was evident that thorough and systematic dusting of the stems and bunches, even without soil treatment, greatly reduced the thrips population. The details of the results of the examinations of the field plots will be found in the two tables accompanying these notes.

COST OF TREATMENT.

Calcium cyanide "A" dust and calcium cyanide flakes are sold at the present time in Brisbane in tins at the rate of 8s. for 5 lb. As 1 lb. of dust should do at least 250 stools, the cost is approximately 9½d. per 100 stools per treatment. The calcium cyanide flakes, at the rate of half an ounce per stool, cost 5s. per 100 stools per treatment, and paradichlorobenzene at the rate of half an ounce per stool works out at 4s. 8d. per 100 stools per treatment.

For dusting stems and bunches one operator should do 50 stools per hour or slightly over an acre per day in plantations where the stools have been planted 12 ft. by 12 ft. apart. With a combined dusting and soil treatment a little less than one acre per day per man should be completed under the above conditions.

CAUTION TO BE OBSERVED IN DUSTING.

It must always be borne in mind that calcium cyanide is poisonous, and must, therefore, not be handled carelessly. Care should be taken, when dusting, to so arrange the work that the operator is moving up into the wind as much as possible, so that the dust is being blown away from

him. The hydrocyanic acid gas is liberated at a comparatively slow rate, and thus allows a margin of safety. The principal danger lies in the inhalation of the dust in breathing, but this may be readily avoided by the exercise of a little forethought.

FIELD APPLICATION OF THE TREATMENT.

As a result of these trials and from other observations made, it would appear that treatments should be made at intervals of not more than three weeks apart for the effective control of the banana thrips.

Treatment should be commenced as soon as the flower-bracts lift off the hands on the young bunch, or even a little before the bunch is thrown.

The most effective control is obtained by dusting the bunches and "stems" under the leaf-sheaths with calcium cyanide "A" dust combined with burying half an ounce of calcium cyanide flakes in the soil at a depth of 3 to 4 in., and at a distance of about 6 in. from the base of the plant, the dosage of flake cyanide being divided into two or three parts.

Even without soil treatment, dusting of the "stems" and bunches will give a very marked measure of control.

ACKNOWLEDGMENTS.

In conclusion, acknowledgment must be made of the great assistance received from those growers who so readily co-operated in every way possible in carrying out the field trials.

KEY TO TABLES.

In the tables showing the results of the field trials with calcium cyanide dust for banana thrips control, the following symbols have been used:—

S. For stem.
B. For bunch.
1. For odd adults but no colonies.
2. For thrips numerous.
3. For small colonies.
4. For large colonies.
x. For stool missing.
s. For thrips scarce.
vs. For thrips very scarce.
S. 3.1. Signifies small colonies composed of a few individuals.
S. 3.2. Signifies small colonies composed of a number of individuals.

The above symbols apply to both plots.

In plot 1, if there is more than one numeral after B, each refers to a separate bunch.

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PLOT No. 1.

	Check.		Section III.					Check.		Section II.					Check.		Section I.				
w.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	x.	x.	x.	S. 1.	S. 1.	S. 1.	S. 1.	S. 3. B. 3.	S. 3. B. 1.3.	S. 1. B. 1.1.	S. 1. B. 1.	S. 1. B. 1.3.	S. 1. B. 1.	S. 1. B. 1.1.	S. 3.2.4.	S. 1.2. B. 3.3.	S. 1. B.1.1.1.	S. 1. B. 3.	S. 1. B. 3.1.	x.	S. 1. B. 1.
	S. 3. B. 3.	S. 3. B. 3.	S. 1. B. 1.	S. 1.	S. 1. B. 1.1.	S. 3.2.	S. 1.	S. 1.	S. 1.3. B. 3.3.	S. 1. B. 1.	S. 1. B. 1.1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.1.	S. 1.	S. 3. B. 3.3.	S. 1. B. 1.1.	S. 1.	S. 1. B. nil	S. 1. B. 1.1.	S. 1.3. B. 1.
	S. 3.1. B. 3.	S. 3.2.	S. 1.2.	S. 3.1.	S. 1.	S. 1. B. 1.1.	S. 1. B. 1.1.	S. 3.2. B. 3.3.	S. 3. B. 1.	S. 1. B. 1. nil	S. 1. B. 1.1.	S. 1. B. nil	S. 1. B. 1.3.	S. 1. B. 1.3.	S. 3.	S. 1. B. 1.	x.	S. 1.	S. 1.	S. 1.	S. 1.
	S. 3.2. B. 1.	S. 3.2.	S. 1.	S. 1.	S. 1.	S. 1.	S. 1. B. 1.1.	S. 3. B. 3.2.	S. 3. B. 1.1.	S. 1. B. 1.1.	S. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.	S. 1.	S. 3.	S. 1. B. 1.	S. 3. B. 1.	S. 1.	S. 1.	S. 1.
	S. 3. B. 3.	S. 3. B. 3.	S. 1. B. 1.	S. 1. B. 1.1.	S. 3. B. 1.	S. 1.	S. 1. B. 1.	S. 3. B. 3.	S. 3.2. B. 3.	S. 1.	S. 1. B. 1.1.	S. 1. B. 1.1.	S. 2. B. 3	S. 1. B. 1.	S. 3. B.3.3.	S. 3.	S. 1.	S. 1. B. 1.3.	S. 3.	S. 1. B. 1.	S. 1.
	S. 3.2.	S. 3.	S. 1. B. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.	S. 1. B. 3.1.	S. 3.	S. 3.2. B. 3.	S. 1.	S. 1. B. 1.	S. 1.	S. 1.	S. 1. B. 1.	S. 3. B. 3.	S. 2.3. B. 3.3.	S. 1. B. 1.	S. 1.	S. 1. B. 3.	S. 1.	S. 1.
	S. 3.	S. 1.	S. 1. B. nil	S. 1. B. 1.	S. 1. B. 1.1.	S. 1. B. 1.1.	S. 1.	S. 3.	S. 3.2. B. 3.3.	S. 1.	S. 1.	S. 1. B. 1.1.	S. 1. B. 1.	S. 1. B. 1.1.	S. 1.	S. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.	S. 1.	S. 1.
	S. 3.	S. 3.2. B. 1.3.	S. 1. B. 1.1.	S. 1.	S. 1. B. 1.1.	S. 1. B. 1.	S. 1. B. 3.	S. 3. B. 3.	S. 1.	S. 1. B. 1.1.	S. 1.	S. 1. B. 1.	S. 1. B. nil	S. 1.	S. 3. B. 3.	S. 3.2. B. 3.	S. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 3. nil	S. 1.
	S. 3.	S. 1. B.1.3.3	S. 1. B. 1.	S. 1. B. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.	S. 1. B. 1.	S. 1.	S. 1.	S. 1.	S. 1.	S. 1. B. 1.	S. 1.	S. 4.	S. 1. B. 3.	S. 1. B. 1.1.	S. 1.	S. 1. B. 1.	S. 1. B. 1.	S. 1. B. 1.
	S. 3.	S. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.1.	S. 1. B. 1.1.	S. 1.	S. 3.2.	S. 3. B. 3.3.	S. 1. B. 1.	S. 1.	S. 1.	S. 1. B. 1.	S. 1. B. 1.	x.	S. 1. B. 1.	S. 1. B. 1.	S. 1.	S. 1. B. 1.	S. 1. B. 1.	S. 1.

PLOT No. 2.

·w.	Check		Section III.					Check.		Section II.					Check.		Section I.				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	S. 3.1.	S.3.2.	S. 1.	x.	S. 1.s.	S. 1.s.	S. 1.	S. 3.2.	x.	S. 1.	S. 1.	S. 1.	S. 1.s.	S. 2.	S. 3.2. B. 3.	S. 3. B. 3.	x.	S. 1.	x.	S. 1.vs.	x.
	S. 3.	S. 3.	S. 1.	S. 1, B. 3.1.	S. 1.	S. 1.	S. 1.vs.	S. 4.	S. 4.	S. 1.	S. 1.	S. 2.	S. 1.	S. 1.	S. 3.2.	S. 2.	S. 1. B. 1.s.	S. 1.s.	S. 1.s.	S. 1.s.	S. 3.1.
	S. 4.	S. 4.	S. 1.	S. 1.	S. 1.s.	S. 1.	S. 3.1.	S. 3.1. B. 3.2	S. 3.2.	S. 1.	S. 1.	S. 1.	S. 1.	S. 2. B. 3.1.	S. 3.2.	S. 3.	S. 1.s. B. 1.s.	S. 1.	S. nil	S. 3.1.	S. 1.
	S. 3.2.	S. 4.	S. 1.	S. 1.	S. 1.s.	S. 3.1.	S. 1.	S. 4.	S. 3.2.	S. 1.s.	S. 1.	S. 1. B. 3.	S. 1.	S. 1.	x.	S. 3.	S. 1.	S. 1.s.	S. 1.s. B. 1.s.	S. 1.vs.	S. 1.vs.
	S. 3.2.	S. 3.	S. 1.	S. 1.	S. 1.	S. 1.vs.	S. 1.	S. 3.	S. 3.	S. 1.s.	S. 1.s.	S. 1.s.	S. 1.vs.	S. nil	S. 3.	S. 3.	S. nil	S. 1.vs.	S. 1.s.	S. 1.vs.	S. 1.vs.
	S. 3.	S. 1.	x.	S. 1.	S. 3.1.	S. 1.s.	S. 1.	S. 3.	S. 3.	S. 1.s.	S. nil	S. 1.s.	S. 1.s. B. nil	S. 1.	S. 2.	S. 3.	S. nil	S. 1.vs.	S. 1.s.	S. 1.	S. 1.vs.
	S. 3.2.	S. 1.	S. 1.	S. 3.1.	x.	S. 1.	S. 1.s.	S. 3.	S. 3.2.	S. 1.s	S. nil	S. 1.	S. 1.	S. 2.	x.	S. 3.2.	S. 1.	S. 1.s.	S. 1.s. B. nil.	S. 1.s.	S. 1.
	S. 3.2.	S. 3.	S. nil	S. 1. B. 3.1.	S. 1.	S. 1.	S. 1.s.	S. 3.	S. 4.	S. 1.	S. 1.s.	S. 1.	S. 3.2.	S. 1.	S. 2. B. 3.2.	S. 3. B. 3.	S. 1.vs.	S. 1.vs.	S. 3.1.	S. 1.vs.	S. 1.
	S. 4.	S. 3.2.	S. 3.1.	S. 1.	S. 1.	S. 1.	S. 3.2.	S. 3.	S. 3.2.	S. 1.	S. 1.	S. 1.	S. 1.	S. 1. B. 1.	S. 3.2.	S. 3.	S. 1.	S. 1.s.	S. 1.	S. 1.	S. 1.
	S. 3.2.	S. 3.1.	S. 3.1. B.1.vs.	S. 1.	S. 1.	S. 1.	S. 1.	S. 3.	S. 3.	S. 1.s.	S. 1.	S. 1.	S. 1.s.	S. 2.	S. 3.2.	S. 3.	S. 1.s.	S. 1.vs.	S. 1.	S. 1.	S. 1.

A. J. CUMMING, Government Printer, Brisbane.

Plate 1. Fruit Showing "Rust," the Injury Caused by the Banana Thrips.

Note the characteristically roughened surface of the affected areas and the gradation of severity of damage in the three fruit. The confines of a colony are well marked in the top fruit near the base.

Photograph taken from: "The Banana Thrips" by J. L. Froggatt
Entomological Leaflet No. 7. Dept. of Agric. and Stock, Queensland, Australia.

Issued May 25th, 1927.

SECTION 7

POISON BARRIER—MIGRATORY PESTS

Poison Barrier — Migratory Pests

Inasmuch as Cyanogas Calcium Cyanide is a chemical which gives off a poisonous gas during a considerable period of time, it was only natural to assume that this material could be used as a poisonous barrier to prevent the migration of an insect pest. One of the most striking examples of such a migratory pest is the chinch bug, *Blissus leucopterus*.

Fig. 1-7.—Chinch Bugs Feeding on Corn Stalk in Missouri.

THE CHINCH BUG

The chinch bug hibernates as an adult, flying to the fields of small grain in early spring, where the eggs are laid and the young are hatched. When the young are but partly grown, the grain hardens and is cut, causing the insects to migrate on foot in search of succulent food. This is usually the neighboring cornfield. (Fig. 1-7).

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earlier recommendations on chinch bug control have failed to properly control the pest in some localities in recent years is unquestioned. How much of this has been due to lack of cooperation on the part of the farmer, we shall not attempt to estimate. However, it is true that for the past several years this pest has continued to extract its annual toll in the corn belt. Our failure to hold the pest is either due to ineffective remedies or inability to get the farmers interested in applying them thoroly. In either case it seems wise that we attempt to find some new and more effective line of attacks. The psychology of something new against the chinch bug is not to be overlooked, when dealing with chinch bug afflicted farmers. This is especially true if the new recommendation proves both effective and practical.

With these general observations we shall proceed to briefly describe the use of calcium cyanide for the control of chinch bugs in Missouri. Much remains to be found out about this new chemical as an insecticide but we have gone far enough to feel sure that it will play an important part in future chinch bug campaigns.

Calcium Cyanide

Calcium cyanide unlike potassium and sodium cyanide is a comparatively new chemical. It has been used successfully for a few years as a fumigant in the tunnels of rodents. George E. Sanders was the first to take special note of this chemical as an insecticide and he interested others in testing it. Flint made some preliminary tests with the material on chinch bugs in the fall of 1922. During the summer of 1923 the material was used on chinch bugs in Indiana, Illinois, Missouri, Kansas and Oklahoma in an experimental way and also quite extensively in practical field control in Missouri.

Calcium cyanide reacts with atmospheric water vapor, giving off hydrocyanic acid gas that makes this new chemical valuable as a barrier to the migrating chinch bugs

Tests on Rate of Emission of Gas

At the outset laboratory and field tests were made to determine the rate and duration of the emission of gas The influence of moisture, temperature and wind were studied In these preliminary experiments only adult bugs were available for use at Columbia, Missouri. In order to make field tests using the immature bugs, the junior author was sent to Oklahoma for several days work. The purpose of these tests was to arrive at some definite conclusions regarding dosage and method of laying down the chemical as a barrier before wheat harvest and chinch bug migration began.

Tests were made with the material dusted or sown broadcast in wheat, scattered along narrow strips, as a line on the surface of the ground, in furrows of different types and covered with dry dust. The powder, granules and flakes were all used.

Broadcasting in Wheat

Some of our first work dealt with the use of the material sown broadcast in the wheat Varying doses of the granules and powder up to 60 pounds to the acre were used. Repeated tests with this later dosage of granules, even with a five to ten mile breeze gave an almost complete kill not only of the chinch bugs but also ground beetles, Colorado potato beetles, grasshoppers, wasps, bees, lady beetles, plant lice and other insects which became enveloped with the gas. The heavier doses also caused some leaf burning. The use of the material for broadcasting in wheat fields was abandoned as impractical, the acreage, dosage and difficulty of application prohibited its use.

Calcium Cyanide as a Barrier

From the beginning the use of the material as a barrier seemed the most logical. In the preliminary tests it was used in a narrow strip two or three feet wide, in a narrow line on the surface of the ground and in a ditch. Dosages were used varying from one half pound to four pounds to each 60 feet. The heavier dosages maintained a killing barrier much longer than the lighter ones. It was soon found that for a line barrier the coarser flakes gave off gas more slowly and therefore lasted longer than either the granules or the powder. Later barrier work, therefore, dealt mostly with the flakes and our final conclusions on dosage refer to flakes rather than granules or the powder.

Narrow Strip Barrier with Trap Crop

The use of the material in a narrow strip was not given a thoro test due to the fact that trap crops had not been planted for the purpose. Several opportunities for testing the material in strips of sorghum were offered and gave satisfactory results with as small an amount as 30 pounds to the acre. After making a few tests with varying dosages it was abandoned for the line barrier. However, with trap crops of cane or sudan grass planted about a month before harvest, we believe from our observations that it will prove practical.

Line Barriers

Our line barriers were made first, on the surface of the ground, second in trenches of varying depths and forms and third, tho only in a few tests, covered slightly with dry dust. It is desirable to keep a

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death line of gas as long as possible and with the least effort and use of material. Hydrocyanic acid gas is of about the same weight as air and when there is no breeze to scatter it, it will hover over the line of flakes whether on the surface of the ground or in a furrow. However, at wheat harvest there is usually a great deal of wind so it is necessary that this be taken into account and guarded against as well as possible.

Line Barriers Applied on Surface of Ground

In our preliminary tests with the surface barriers we used from one half pound to four pounds of granular cyanide to sixty linear feet of barrier The smaller dosage applied when there was a six-mile wind, killed adults bugs which attempted to cross, for only one hour. The heaviest dosage, applied under the same conditions, remained effective for from three to five hours and killed some bugs five feet from the line due to drifting of gas. These also burned the lower blades of wheat. A dosage of one pound to sixty linear feet of barrier on the surface of the ground remained effective for only about two hours on the average. The drifting of the gas from a surface barrier is too great for most effective results.

Line Barriers Applied in Furrows

Furrows may be made of various shapes and forms and our results show that a narrow, deep furrow gives far better results than do those of other types.

In our first tests we used a hoe and a hand plow to make a shallow ditch from one to three inches deep. This showed a decided improvement over the line on the surface of the ground due mostly to the fact that it retarded the progress of the bugs and kept them longer in the gas area. A very shallow ditch does not help materially in checking the drifting of the gas, but it will keep the bugs busy longer climbing out of the gas area.

A deep furrow made with a plow and rounded out with a post, was then used This provides a definite container for the gas and where there is no breeze it should be expected to work well. However, in our tests it was found that a broad rounded-out furrow of this type allowed the gas to spread out in the furrow, and it permitted the wind to blow it out readily. The broad furrow in our tests gave no better results than a narrow shallow furrow made by hand. However, it does provide for the possibility of combining a mechanical barrier with the gas barrier

To chinch bug workers it is a well known fact, that normally at harvest the bugs move mostly during a few hours of the day and only

light scattering movement occurs during the rest of the day. When the gas and mechanical barriers are combined the log, as in the ditch-log barrier, can be kept moving thruout the morning when but few bugs are moving, and then the gas barrier laid down in the afternoon when heavy movement starts.

However, Missouri farmers prefer either to fight all the time with the ditch-log or to use the gas alone. Only a few reported using the combined barriers.

In our tests the broad, rounded furrow with one pound of calcium cyanide to sixty feet remained effective for only two or three hours and did not prove entirely effective thruout the afternoon migration.

The type of furrow used most in Missouri was a plowed furrow with, the dirt thrown toward the wheat stubble and the side next to the corn as nearly as possible a vertical wall. This is the type of furrow most farmers make and we have found it to be the most effective. This is probably due to the fact that it provides the best protection against the drifting of the gas and the concentrating of gas at the foot of the vertical wall. The vertical wall is also an effective barrier up which the bugs, already weakened by the gas, are unable to climb. In such a furrow one pound of calcium cyanide flakes to each sixty feet applied in the early afternoon proved effective in preventing bugs crossing for the rest of the day. This is the dosage and type of furrow and method of application which gave us best results this summer. Likewise, this is the type of barrier used by most of the farmers in the state. Our tests were made in different counties in the northern part of the state thruout the migration period. The migration was later than normal and more drawn out than usual which made the use of any type of barrier more difficult than under normal conditions. We believe, therefore, that in a normal season with a heavy active migration of bugs, the gas barrier would have worked more rapidly, cleaned up the bugs in fewer days and thus proven more effective and cheaper. Still our results last summer were highly satisfactory and the farmers using the material were pleased with their results as the following summary of their reports will show.

Sixty-five questionnaires were sent out to Missouri farmers, who used calcium cyanide for chinch bug control, and thirty-three replied. Of these, twenty used the material in a furrow and all reported success even tho four used less than one pound to sixty feet of barrier a day. Thirteen used other methods and all but one of these reported satisfactory results. Of those following directions only one considered the

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material too expensive. This is further attested to by the fact that the Missouri Farmers Association, an independent organization of some 70,000 Missouri farmers have just recently contracted for a minimum of twenty tons for their 1924 chinch bug campaign.

Summary

(1) Calcium cyanide flakes used in a properly prepared furrow at the rate of one pound to sixty linear feet once a day proved an effective chinch bug barrier in Missouri. The material in such a barrier cost about four dollars a day for a fourth of a mile of barrier.

(2) For best results it should be applied in the early afternoon or when the daily migration begins.

(3) A narrow, deep furrow with a vertical wall next to the crop to be protected proved to be the best type of furrow in which to apply the calcium cyanide flakes.

(4) Other type of furrows or methods of applying the chemical did not prove so effective.

(5) Temperature, moisture and wind are factors influencing the success of such a barrier

Fig. 2-7.—Chinch Bug Injury to Corn in Missouri.

Fig. 3-7.—Applying Cyanogas Chinch Bug Flakes in Furrow to Form Barrier. Note Perpendicular Wall Next to Corn.

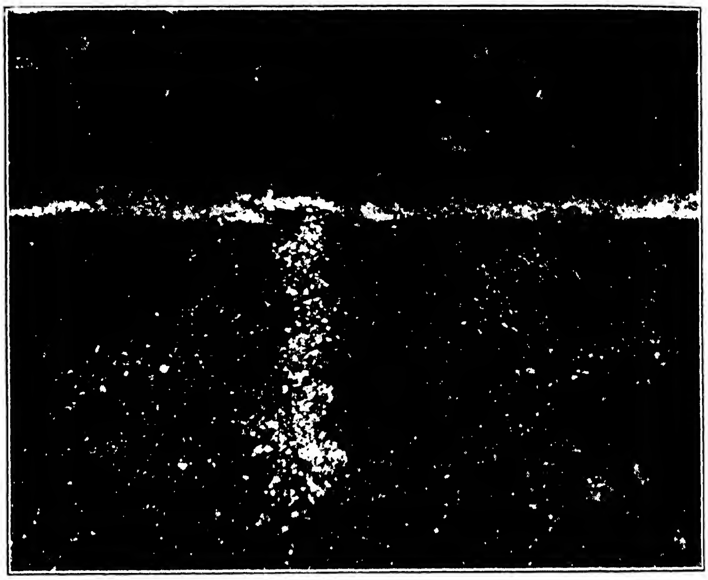

Fig. 4-7.—Wing of Chinch Bug Flakes Used with Creosote Barrier. Note Dead Chinch Bugs on Each Side of Calcium Cyanide Wing.

The results obtained by Professor W. P. Flint of the University of Illinois were published as Bulletin 249, Illinois Agricultural Experiment Station, May, 1924. Further experiments were conducted in Kansas in 1924, adapting Cyanogas Calcium Cyanide to the control of the chinch bug under the dry windy conditions encountered in that state. The results obtained by Professor J. W. McColloch were published as Circular 113 of the Kansas State Agricultural College, June, 1925. The portion of this paper which deals with the use of Cyanogas Calcium Cyanide in conjunction with a creosote barrier follows the reproduction of Illinois Bulletin 249.

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UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 249

CALCIUM CYANIDE FOR CHINCH-BUG CONTROL

IN COOPERATION WITH THE NATURAL HISTORY SURVEY, ILLINOIS DEPARTMENT OF REGISTRATION AND EDUCATION

By W. P. FLINT and W. V. BALDUF

PORTION OF A CALCIUM CYANIDE STRIP USED AT RIGHT ANGLES TO A CREOSOTE BARRIER, SHOWING DEAD CHINCH-BUGS WHICH HAVE ATTEMPTED TO CROSS

URBANA, ILLINOIS, MAY, 1924

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SUMMARY

Calcium cyanide is a substance having the appearance of slate, which on exposure to moisture gives off hydrocyanic acid gas. In sufficient quantities, it is deadly to all forms of plant and animal life.

The use of this chemical as a means of combating chinch-bugs was first tried in Illinois. Extensive tests were begun in 1922 and were continued thruout the season of 1923. In 1923 similar tests were made in a number of other states, particularly in Kansas, Missouri, and Indiana. While it is impossible to make definite recommendations as to its use from the results of two years' work in Illinois, it is believed that farmers will be warranted in trying out some of the methods described herein.

The best results from calcium cyanide have been obtained by using either the dust or the granules in combination with creosote or coal-tar barriers. Six-inch strips of the cyanide, requiring about one ounce to a strip, laid at right angles to the barrier every two rods, have under favorable conditions killed 75 to 95 percent of the bugs as they moved along the line of the barrier. This chemical was also very effective when dusted along the line of a coal-tar or creosote barrier.

Fair to good results have been obtained by dusting calcium cyanide in trap strips of crops sown between fields of small grain and corn. However, only one year's data have been obtained with trap crops.

Barriers of calcium cyanide alone were not so effective as the other methods and at the same time were more costly.

Hydrocyanic acid gas given off by calcium cyanide, is very poisonous, and the directions for handling given on page 84 should be carefully noted.

CALCIUM CYANIDE FOR CHINCH-BUG CONTROL[1]

By W. P. FLINT, Entomologist, State Natural History Survey, and W. V. BALDUF, Assistant Professor of Entomology, University of Illinois

Calcium cyanide was first used in 1922 as a means of combating chinch-bugs around the margins of infested fields of small grain. Experiments were continued thru the season of 1923, a large number of tests being made during the latter season. In the first experiments this material was used alone as a barrier. The results showed it to be very effective, under some conditions killing every bug that came in contact with it, but its use in this way was so costly as to make it unpractical for general use on Illinois farms. Later experiments, however, showed that it could be used in combination with creosote and coal-tar barriers, thus greatly increasing their effectiveness without increasing the cost to a point where its use would be unpractical.

While definite recommendations of the best way to use calcium cyanide cannot be made from the results of two years' work, the results here presented will enable the Illinois farmer to judge for himself the best method of using this material on his farm.

In the Illinois experiments, four methods of using this chemical were tested:[2]

1. Laid in strips at right angles to a creosote or coal-tar barrier
2. Dusted or scattered along a creosote or other barrier at the time of day when the bugs are most numerous
3. Dusted over strips of trap crops sown between infested small grain and corn
4. Alone as a barrier around the margins of the infested field

[1] Note.—Calcium cyanide is a cheap form of rather low-grade cyanide. It has about half the strength of the sodium cyanide generally used in hydrocyanic acid gas fumigation of fruit trees, greenhouses, and flour mills. When this chemical is exposed to air containing the usual amount of moisture, or is applied to damp soil, the poisonous hydrocyanic acid gas is liberated in sufficient quantities to kill insects or other animals exposed to it, for varying periods of time.

[2] Some tests were also made to determine the effect of calcium cyanide dust when applied directly to corn. While it proved very effective in killing the chinch-bugs clustered on the plants, it cannot be used for chinch-bug control because it nearly always penetrates the curl of the leaves and causes the death of the plant or a severe burning. A 2-percent nicotine dust used in this way is just as effective as calcium cyanide dust in killing the bugs, is cheaper, and does not injure the corn.

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Three forms of calcium cyanide were tried out: (1) flakes, which have the appearance of finely broken slate, the separate flakes being from one-fourth to one-half inch across and about one sixty-fourth inch thick; (2) granules, having the same form as flakes but being much finer, the larger particles being only about one-eighth inch across; (3) dust, the material ground to a fine powder.

USED IN STRIPS AT RIGHT ANGLES TO A CREOSOTE OR COAL-TAR BARRIER

In 1923 the method of control proving the most practical was the use of calcium cyanide strips laid at right angles to the creosote or coal-tar barrier. These strips are made by putting down one to one and one-half ounces of cyanide in each strip, laid from three to five inches wide and from six to eight inches long. These strips are made at right angles to the barrier, touching the creosote on the side next the stubble field. They should be spaced every two rods along the line. In the corners of the field, where the bugs usually gather in greatest number, it may be necessary to lay the strips closer together.

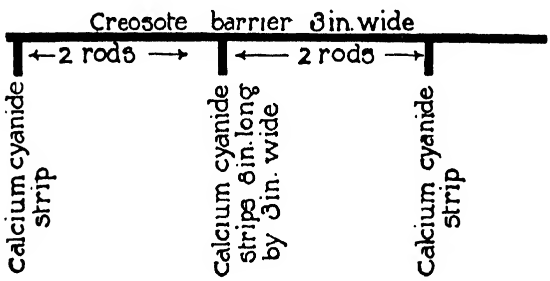

FIG. 1.—DIAGRAM SHOWING THE METHOD OF LAYING CALCIUM CYANIDE STRIPS AT RIGHT ANGLES TO A CREOSOTE OR COAL-TAR BARRIER

Care should be taken that the strips actually connect with the barrier. The slope toward the barrier should be gradual so that the cyanide will not roll down and away from the creosote or coal tar.

Chinch-bugs attempting to leave the fields of small grain and encountering barriers of creosote or coal tar are repelled by the odor of these substances. In the case of coal tar, they are held back by the stickiness of the material as well. Hence they turn and start along the stubble side of the barrier, seeking an opening thru which they can escape into fields of corn or to other food plants. Half-grown young, or nymphs, travel along the barriers at the rate of five to six

feet a minute, and are almost sure to encounter a cyanide strip in five minutes or less after they get to the barrier.

Tests of this method extended over a period of two months in 1922 and a somewhat longer period in 1923, and were made under varying weather and soil conditions. Under some conditions pure dust was found to be the most effective form to use. When the soil is wet, the granules are better than the dust because they do not lose their strength so rapidly. The flakes also give better results than the dust when the ground is wet, but they are not very effective when the soil is dry or when the wind blows briskly. In general, granular calcium cyanide is the most practical form.

Care should be taken that the strips actually connect with the creosote barrier. The slope toward the barrier should be sufficiently gradual so that the cyanide will not roll down and away from the creosote.

A sprinkling can from which the sprinkling cap has been removed is a convenient vessel to use for pouring the cyanide. After a little practice one is able to quickly put down strips of approximately one ounce each at the intervals specified.

STRIPS ARE EFFECTIVE FOR A LIMITED TIME

When the soil is dry and the wind strong, most bugs can cross the cyanide strips without being killed. Under more favorable conditions, however, the strips are effective up to five or more hours. Usually on warm bright days, the heavy movement of chinch-bugs starts between 2:30 and 3:30 in the afternoon, the bugs gathering along the barrier in greatest numbers between 3:30 and 5:30. The most effective kill can therefore be made by laying the strips between 3:00 and 4:00 o'clock in the afternoon. Except when the soil is dry and the wind high, strips laid at this time remain effective for the rest of the afternoon and may be counted on to kill 75 to 95 percent of all bugs reaching the barrier.

If the amount of cyanide in the strips is doubled, and the flake or granular form is used, some bugs will be killed the following forenoon, if no rain has fallen during the night; but the strips will not remain effective during the entire day. Since the bugs seldom migrate in large numbers in the morning, the kill is not sufficiently increased to warrant the added expense of using these larger amounts of cyanide.

Occasionally on cloudy days there is a considerable movement of chinch-bugs all day. In such weather the cyanide should be applied between 9:00 and 10:00 o'clock in the forenoon, and another application made in the afternoon if necessary. *Because the creosote or coal-tar barrier holds the chinch-bugs in the field, it is very seldom necessary to make more than one application a day, even during cloudy weather.*

Expense of Combined Barrier

The total cost for a quarter of a mile of creosote or coal-tar barrier and cyanide strips along it is about $21 for the migration period. This is figuring cyanide at 20 cents a pound delivered at the local shipping point and the cost of creosote or coal tar at $5 to $7 for the season. This will not be thought too expensive to be practical if one remembers that he is not only stopping the bugs but is actually killing the majority of them. Post holes are unnecessary where calcium cyanide cross-strips are used, for the cyanide kills more bugs than are usually caught in the post holes. The saving of the labor of digging the post holes helps pay the expense of the cyanide.

USED ALONG A CREOSOTE OR COAL-TAR BARRIER

The second method of using calcium cyanide in combination with a creosote or coal-tar barrier is to distribute small amounts along the barrier, on the side of the field of small grain, instead of in strips at right angles to the barrier. To be effective, the calcium cyanide should be laid down each day when the bugs are gathering in greatest numbers. For this method, the cyanide dust has been found most practical.

The expense of this treatment is somewhat higher than that of the right-angle strips, but on windy days, when the soil is very dry, it is more effective and more convenient than the strips. The cost of the calcium cyanide is from $1 to $1.50 a day for each quarter-mile of barrier.

This method has the disadvantage of requiring a close watching of the barrier, for in order to get a maximum kill the dust must be applied when the bugs are present along the barrier in greatest numbers. While this is usually about 4:30 in the afternoon, the time may vary a great deal with weather conditions. One application a day is necessary. This kills all the bugs massed against the barrier at the time and those coming into the dusted area for ten to thirty minutes thereafter. The duration of the kill depends upon weather conditions.

How to Apply the Dust

The calcium cyanide dust may be applied with a blower duster or a homemade shaker. The duster is of the type commonly used for dusting truck crops or small fields of cotton; it costs from $10 to $25, and is apparently no more effective for this purpose than a homemade shaker. A convenient and efficient shaker can be made in the following way:

Obtain a gallon or half-gallon tin pail with a tight-fitting lid. (The lid is important in confining the fluffy and poisonous dust.) Make an

extension bail by nailing narrow strips of wood eighteen inches long to opposite sides of the pail and joining them above with a piece of broom stick. (The extension bail enables the operator to walk erect and at the same time to distribute the material close to the ground so that it will not be carried away by the wind.) From the outside of the pail, punch four to six holes per square inch in the bottom, using an eight-penny nail.

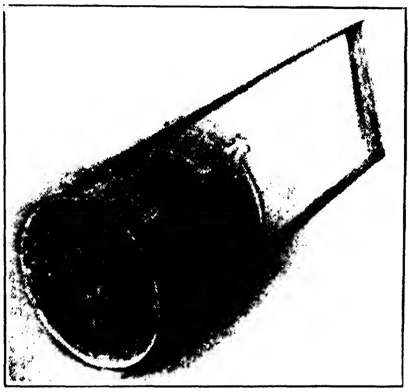

FIG. 2.—HOMEMADE SHAKER FOR APPLYING CALCIUM CYANIDE DUST

This shaker must have a tight-fitting lid to prevent the escape of the poisonous dust.

Fill the pail two-thirds full of dust and walk along the barrier, forcing the material out by a jiggling motion. The dust may be applied as rapidly as one can walk down the side of the field. Approximately one pound of the dust to thirteen rods of barrier was found to be effective.

DIRECTIONS FOR MAKING A CREOSOTE BARRIER

A creosote barrier is made by throwing up a ridge of earth around the infested field of small grain and applying creosote along the brow of the ridge on the side toward the field of small grain. The furrow should be turned away from the grain field.

The creosote is applied with a galvanized or tin bucket having a six-penny nail punch in the side near the bottom. The stream of creosote should be directed against the brow of the ridge on the side toward the field of small grain, as above stated, so that the bugs in attempting to leave the field will crawl up to it. The creosote must be renewed once a day during the first week, and should always be ap-

plied on the same line. After the first week an application every other day is usually sufficient.

The application should be made usually about 1:00 o'clock in the afternoon, before the bugs have gathered along the line. It is the odor

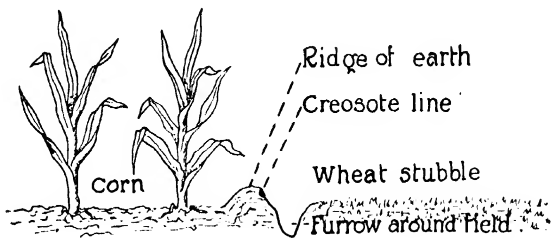

FIG. 3—CONSTRUCTION OF A CREOSOTE BARRIER USED ALONE

Where calcium cyanide strips are to be used with the creosote or coal-tar barrier, the slope of the ridge should be more gradual than shown here.

of the creosote that keeps them from crossing the barrier; consequently if the line is renewed when the bugs are massed against it, many become confused by the strong smell of creosote in the air and run over the barrier.

A barrel of creosote, on an average, is required to maintain a half-mile of barrier during the period the bugs are leaving the wheat stubble. The creosote should preferably be of a grade with a high napthalene content.

A line of ground limestone is sometimes spread along the brow of the ridge and the creosote applied on this line. Limestone retains the odor of creosote better than does the soil and so increases somewhat the effectiveness of the barrier.

DIRECTIONS FOR MAKING A COAL-TAR BARRIER

Coal tar may be used as a barrier in much the same manner as creosote, but the ground on which it is poured should be nearly level and should be compacted as firmly as possible, and a larger quantity of coal tar than of creosote will need to be used.

It must be borne in mind that the effectiveness of the coal-tar barrier depends largely on its sticky character. It will have to be renewed more frequently than the creosote, and since about twice as much coal tar as creosote is required, this kind of barrier usually costs more than one of creosote.

Coal tar for this work may be obtained from gas plants in any of the larger cities. There is a wide difference in the grades that may be obtained from different plants. Coal tar which contains practically all the creosote is much more effective for barriers than that from which a part of the creosote compounds have been distilled.

USED ON TRAP CROPS

Many attempts have been made to control chinch-bug migrations by stopping the bugs in narrow trap strips of their favorite food plants sown between the small grain fields and the fields of corn or other crops to be protected. There seemed to be a possibility of using calcium cyanide with such trap crops by applying it when the bugs were gathered in the trap strips, and in 1922 some experiments were made with this method. No special trap crops had been sown, but strips of wild grasses growing between the small grain and the corn were dusted with calcium cyanide and a fair kill of bugs was obtained.

In 1923 this trap crop and cyanide combination was tested more thoroly. Strips of oats, millet, Sudan grass, and corn were sown between heavily infested fields of small grain and of corn. These strips were treated with flake, granular, and dust calcium cyanide at varying intervals and at varying rates of application. Altho these tests extended over the migration period of one season, the results were not conclusive. Apparently this method is not so effective as the creosote barrier with the cyanide laid along it or in strips at right angles to it. However, the method may be worth trying under some conditions.

Of the trap crops used on the University Farm in 1923, Sudan grass was decidedly the most effective. It is very attractive to chinch-bugs and withstands a considerable amount of feeding by them before it is killed. It is vigorous, and hence can also endure the bruising by teams and machinery which occurs in cultivating the corn. It is not easily killed by heavy applications of calcium cyanide, and the sheaths of the leaves fit so tightly to the stems that chinch-bugs cannot get between them and the stalk and thus be protected from the fumes of the gas. The rows of Sudan grass should be sown thickly and close together so that a bug can scarcely pass thru the strip without encountering a plant.

Some tests with rye made during the latter part of the summer showed that this plant is apparently second to Sudan grass as a trap crop. It is hardier than oats and nearly as attractive to the bugs as Sudan.

Millet and oats were found to be quite susceptible to cyanide.

Corn, even when seeded with a drill, formed a very poor trap crop, many bugs going thru the strip and into the field of corn beyond. The

corn was also very susceptible to the effects of the cyanide dust, one or two dustings killing the plants.

From the results of this work thus far, the following statements can be made:

To be in the best condition for stopping the bugs, a trap crop should form a thick, close covering over the ground and should not be more than six inches high at the time the chinch-bugs migrate. For this reason, the trap strip should not be sown when the corn is planted,

FIG. 4.—DUSTING A TRAP-CROP STRIP WITH A BLOWER DUSTER

The trap crop shown here is Sudan grass, which is somewhat higher than it should be for this purpose. To get the best results, the trap crop should not be more than six inches high.

unless rye is used. Sudan grass should be planted one to two weeks after the corn is in the ground. The time of planting depends, however, on the expected time of small grain harvest and not on the size of the corn. The trap strips should be three and one-half feet or more wide, and to insure a thick growth, they should be sown with about one and one-half times the usual amount of seed.

In this method of using calcium cyanide, dust was found to be the most desirable form.

The dust may be applied to the trap crops by means of a duster or a homemade shaker. The shaker is not so good for this purpose as the regular blower duster; however, it gives a very fair distribution of the dust providing the trap strip is not more than six inches high. The trap strips must be dusted once a day when a heavy migration of the bugs is taking place. The dusting is most effective when done between 4:30 and 5:30 in the afternoon.

Judging from experiments made thus far at this Station, calcium cyanide dust must be applied at the rate of about one pound for each two and one-half rods of trap strip three feet wide. This is at the rate of one pound of dust to each one hundred and twenty square feet. Under favorable conditions, such an application kills from 80 to 95 percent of the bugs gathered in the strip, but when the wind is strong and the crop dry, the results are not nearly so good. The amount of kill seems to depend in a general way on the amount of moisture present in the trap crop, the velocity of the wind, the height and density of the trap strip, and perhaps some other factors.

Calcium cyanide granules may be used in treating these trap strips and can be applied by hand at the same rate as the dust. Where the trap crop is wet with rain or dew, the granules are seemingly fully as effective as the dust, but on dry soil and plants they do not result in so large a kill.

The above statements are not to be taken as definite recommendations for the use of the trap strip and calcium cyanide combination for chinch-bug control. It will be necessary to carry on experiments for one more season at least before definite recommendations can be made.

USED ALONE AS A BARRIER

More than three hundred separate tests have been made in Illinois to determine the practicability of the flake, granular, and dust forms of cyanide used alone as chinch-bug barriers. Under favorable conditions it was found that nearly all the bugs attempting to leave a field of small grain on foot may be killed along such a barrier, if a sufficient amount of the cyanide is applied. Under less favorable conditions, however, the results were extremely variable. In some kinds of weather, one-half to one-fourth pound of cyanide per rod of barrier killed all bugs attempting to cross it during a period of three to five hours. With other weather conditions, the same amount permitted 50 percent of the bugs to cross in fifteen to thirty minutes after it was applied.

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In these tests, the calcium cyanide was used in various positions and at various rates. It was used on soil from which all vegetation had been removed, on the top of the plow furrow ridge, in strips in the stubble (which protected it somewhat from the action of the wind and sun), and in the bottom of a plowed furrow or trench dug around the margins of the field. Only when used in a furrow or trench did it give promise of having practical value as a barrier, under the conditions encountered. Used in this way the gas is somewhat confined, and if the soil is damp and little or no wind blows down the furrow, the gas accumulates sufficiently to kill most of the bugs over a considerable period of time. If the soil is dry, and the wind is strong along the furrow, the kill is small, even when the cyanide is used in the bottom of the furrow.

In Table 1 are shown the results of 144 tests of cyanide used in the furrow; they give an idea of the diverse effects of the chemical under different weather conditions encountered.

TABLE 1.—EFFECTIVENESS OF VARIOUS AMOUNTS AND FORMS OF CALCIUM CYANIDE USED ALONE IN THE FURROW AS CHINCH-BUG BARRIERS

Form	Amount used on each rod of barrier	Number of tests	Average time during which 90 percent of bugs were killed	Variation in time during which 90 percent of bugs were killed
	lbs.		*hrs.*	*hrs.*
Flakes....	4	3	8¾	3 to 20
Flakes.....	2	3	8½	1 to 17
Flakes.....	1	18	4	½ to 15
Flakes.....	½	15	1½	½ to 5½
Flakes.....	¼	17	1¼	¼ to 4
Flakes.....	⅛	4	¾	¼ to 1½
Granular...	2	3	4¾	1 to 10
Granular...	1	15	3¼	½ to 17
Granular...	½	12	1¾	½ to 5
Granular...	¼	13	1½	½ to 6
Dust, pure .	4	1	5	......
Dust, pure .	2	1	5	......
Dust, pure .	1	13	3½	1 to 5
Dust, pure .	½	11	2½	½ to 6
Dust, pure .	¼	10	1¼	½ to 3
Dust, pure .	⅛	5	¾	½ to 1

On still, damp days, one-half to one-fourth pound of flakes, granules, or dust of calcium cyanide to a rod makes an ideal barrier in a furrow five to seven inches deep. The cyanide should be applied on the furrow bottom at the point farthest from the grain stubble. The bugs are then forced to climb up the steep side of the furrow directly above the cyanide, and as a result, their movements are slowed up. Thus they are exposed to the gas for a longer time than when the cyanide is placed in the middle of the furrow or along the side down which they tumble in leaving the stubble.

As may be seen from Table 1, where one-fourth to one-half pound of calcium cyanide per rod was used, it was in some cases effective for as long as six hours. Under such conditions, the cyanide applied at 1:00 o'clock could be depended upon to kill 90 percent of all the bugs

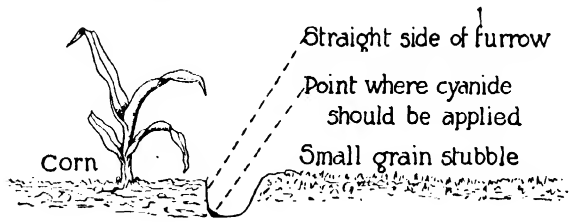

FIG. 5.—MOST EFFECTIVE CONSTRUCTION OF A CALCIUM CYANIDE BARRIER

The straight side of the furrow should always be toward the corn, and the calcium cyanide should be laid at the base on this side, as shown above. If a trench is dug, the cyanide should be applied at the same point.

attempting to leave the field during the afternoon. In other cases, the same amounts of cyanide applied in the same way and in the same places were effective only for fifteen to thirty minutes; that is, it would be necessary to make three to five applications to maintain an effective barrier during an afternoon.

Used at the rate of one-fourth of a pound per rod, an amount of calcium cyanide sufficient to maintain a barrier a quarter of a mile long would cost \$4 a day. This figure is based on a price of 20 cents per pound for the cyanide delivered at the farmer's shipping point. For a fourteen-day migration period, material for a quarter-mile of barrier would cost \$56. The experiments show that on a number of days two or three times this amount of cyanide would have to be used; therefore one can hardly count on maintaining an effective barrier for the season at less than \$70 to \$75 for each quarter-mile. This is nearly three times the expense of killing the bugs with a combination of creosote and calcium cyanide, or nearly ten times the cost of maintaining a creosote barrier.

Because of the great variation in the results of experiments made to date, definite recommendations for the use of cyanide alone as a barrier cannot be made at this time. During the past season work similar to that done in Illinois has been carried on in Kansas, Missouri, and Indiana. Rather favorable results have been obtained with the barriers in Missouri. The results in Kansas and Indiana compare very closely with those obtained in Illinois. Judging from all the tests made, it may be said that a chinch-bug barrier can be maintained by the use of calcium cyanide alone, but that the expense of maintaining

such a barrier is so great as to make it unpractical except for the protection of a very valuable crop, such as seed corn.

Of the different forms of calcium cyanide tried for barrier work, the dust has, on the whole, given the best results, mainly because of its physical character. The small particles afford unstable footing for the bugs when they attempt to cross the line. This retards their movement, and they are exposed to the gas for a considerably longer time than when trying to cross a line of flakes or granules. These coarser forms of the cyanide evolve the gas more slowly than the dust, and do not greatly retard the movements of the bugs. On the other hand, when the soil is very damp, the dust gives off its gas so rapidly that it soon weakens and does not continue to kill over a very long period. Under such conditions the coarser forms of cyanide are to be preferred.

HOW TO HANDLE CALCIUM CYANIDE

Caution is necessary in handling calcium cyanide. The gas given off from this material is one of the most deadly known. However, the calcium cyanide used for chinch-bug control is comparatively weak in hydrocyanic acid gas, and if one is careful not to get his head directly over the container, or to breathe in the dust or the fumes of the freshly opened cans, there is little danger. There is apparently very little hazard in handling the material in the open air if one keeps on the windward side of the container. The writers have worked with it for the past two seasons, and have purposely tested the effects upon themselves in a number of different ways. Occasionally when enough of the dust was breathed into the nostrils, particularly when the distributing utensils were being filled from the larger cans in which the material was shipped, a severe headache was caused. This discomfort disappeared after an hour or two in the open air; but one must be careful at all times. *Cyanide should not be left in the field or around buildings where children or farm animals might possibly reach it.* Fowls that have access to it sometimes pick up the flakes or granules, with fatal results.

THE CREOSOTE BARRIER

Extensive experiments during the migration period of 1924 demonstrated that the creosote barrier was the most practical and efficient type of chinch bug barrier for Kansas conditions. The use of creosote as a barrier material was developed in Illinois, and the methods of using it in Kansas are, with slight modifications, similar to those recommended in that state.

The creosote barrier is made by plowing a furrow between the infested and noninfested fields, the dirt being thrown away from the former field. A line of creosote from one-half to three-fourths of an inch wide is then poured near the top of the ridge on the side nearest to the noninfested field. The creosote is best applied from a gallon bucket having an eight-penny nail hole in the center of the bottom. By using a long wire bail, the operator can walk along the barrier, directing the stream of creosote on the desired line. (Fig. 2.)

Creosote can also be poured from a sprinkling can, the nozzle of which has been removed and the opening partially closed with a wooden plug. (Fig. 3.) This method, however, requires a little more time, since the operator has to stoop over while pouring the material. In using creosote, it is necessary that the line be renewed daily during the period of heaviest migration. Since the bugs usually do not begin moving until about 3 o'clock in the afternoon, it is not necessary to apply the creosote until shortly before the daily migration starts. Each application should be made along the same line; since the efficiency of the barrier increases with the number of applications.

Creosote is merely a repellant agent and does not kill the insects. The bugs, on approaching the barrier, are repelled by the odor, with the result that they turn and follow along the line. Two methods may be used for killing the bugs as they travel along the barrier. The most effective one is to dig postholes at intervals of

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about a rod. These holes should be about 12 inches deep and the rims flared somewhat. Wings of creosote should extend at right angles out past the holes two or three feet in order to guide the bugs into the trap. (Figs. 1A and 2.) The bugs are killed by

FIG. 2.—A creosote-posthole barrier showing method of pouring creosote with a long-handled gallon bucket.

placing from one-fourth to one-half of an ounce of calcium cyanide in each hole daily.

The other method of destroying the bugs is to place wings or piles of flake calcium cyanide at right angles to the barrier line at intervals of 12 to 16 feet. These wings of cyanide should be triangular

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in shape, the base resting on the line of creosote. (Fig. 1*B*.) From one to two ounces of cyanide should be used for each wing and must be renewed daily when the migration starts. This method gives good control when the bugs are small and when there is plenty of soil moisture and little wind, but is not satisfactory when there is a strong breeze or low humidity. This difficulty may be overcome to some extent by packing and sprinkling the soil before placing the cyanide.

Data on the cost of the creosote-posthole barrier were obtained in connection with the experimental work, and it was found that an efficient barrier could be constructed and maintained during a migration period of 10 days for approximately $60 per mile. Under ordinary circumstances, a barrel of creosote is sufficient for each one-half mile of barrier. The cost per mile of the creosote-posthole barrier for a 10-day period in 1924 is summarized as follows:

Creosote, 2 barrels @ $10 a barrel	$20.00
Labor, 3 hours a day @ 25 cents an hour	7.50
Calcium cyanide, 100 pounds @ 18 cents a pound	18.00
Miscellaneous, plowing furrow, digging postholes, etc.	12.00
Total	$57.50

Where wings of calcium cyanide are substituted for the postholes, the expense will be somewhat increased and the efficiency reduced. The minimum cost of constructing and operating one mile of this type of barrier for 10 days in 1924 is itemized as follows:

Creosote, 2 barrels @ $10 a barrel	$20.00
Labor, 4 hours a day @ 25 cents an hour	10.00
Calcium cyanide, 210 pounds @ 18 cents a pound	37.80
Miscellaneous, plowing furrow, etc.	7.00
Total	$74.80

The efficiency of the creosote barrier with either postholes or wings of cyanide was demonstrated by the fact that not a single hill of corn or sorghums was killed in the barrier-protected fields, while on many farms in the vicinity, from 40 to 100 acres of unprotected row crops were destroyed. Careful counts and estimates showed that at no time did more than 1 per cent of the migrating bugs cross the barrier, and during most of the period less than one-tenth of 1 per cent succeeded in crossing. Some idea of the number of bugs along this barrier is indicated by the fact that more than 400,000 bugs were caught in a single small trap between two wings of cyanide during one afternoon. During the height of the migration, the bugs were passing a given point on the barrier at the rate of 3,800 per minute.

The advantages of the creosote-posthole barrier may be summarized as follows: (1) It is effective under all conditions and the cost is not prohibitive. (2) The labor item is reduced to a minimum. (3) Creosote will remain effective for a period of 24 hours thus holding any migration that may take place during the morning. (4) Calcium cyanide in the postholes takes care of the prob-

FIG. 3.—Tar barrier showing method of pouring tar or creosote from a sprinkling can.

lem of destroying the bugs after they are trapped. (5) Creosote comes in convenient containers and is easily handled. (6) Creosote has many uses on the farm, so any material not used in chinch-bug control is not wasted.

METHODS OF APPLICATION

The methods in the use of Cyanogas Calcium Cyanide in the control of chinch bugs, migrating from one field to another, may be briefly summarized as follows:

Barrier Method: The barrier is made by plowing a narrow, deep furrow between the wheat and the corn field with the perpendicular side of the furrow next to the corn. Cyanogas Chinch Bug Flakes are distributed at the bottom of the furrow in a compact strip, about three inches in width, using one pound to each sixty feet. (Fig. 3-7). This should be done each day of the migration period just before the heavy movement of the bugs begins, which ordinarily occurs about mid-afternoon.

There is an evolution of gas from the flakes, stronger at first and gradually diminishing, which kills any bug attempting to cross or getting into the trench. The amount of material described above should maintain a killing concentration of gas for several hours covering the migration period of each day which lasts for about four hours.

In some states where the soil is quite dry, the moisture in the air may not be sufficient to produce a rapid evolution of the poisonous gas after one or two hours. Under these conditions, sprinkle the ditch lightly with water from a sprinkling can, walking as rapidly as possible to prevent drenching.

Calcium Cyanide Wings with Creosote Barriers: In case a creosote or tar barrier is used, it has been customary to dig post holes at intervals behind the barrier for the purpose of trapping the chinch bugs. Short strips of Cyanogas Chinch Bug Flakes at right angles to the creosote barrier have been successfully substituted for the post holes with the result that when the bugs move along the barrier seeking a crossing place, they reach these cross strips and die. (Fig. 4-7). Thus the post holes are unnecessary, since the Flakes kill more bugs than usually are caught in the holes.

The Trap Crop Method: The trap crop method has proven easy and effective, but requires forethought on the part of the grower. In using this method, a trap crop of Sudan grass, rye, sweet cane or sorghum, millet, or similar favorite food plant of the chinch bug is planted between the wheat field and the corn field.

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The strip should be from four feet to a rod wide and planted thickly, about four weeks before wheat harvest, so that the plants will not be too tall at the time of the chinch bug migration. Chinch bugs migrating from the wheat stubble will stop in the trap crop to feed. Every twenty-four or forty-eight hours, when the plants are dry, the farmer should broadcast Cyanogas Chinch Bug Flakes along this strip at the rate of fifty to one hundred pounds per acre.

The gas given off by the flakes will kill the bugs in the trap crop. When a new lot of bugs have collected in the strip they should again be treated.

Locusts

In view of the successful experiments in the control of chinch bugs and of certain preliminary tests in the control of grasshoppers in the United States, it was decided to carry out a series of experiments to determine the effectiveness of Cyanegas Calcium Cyanide for the control of migratory locusts.

To carry out these experiments, our Mr. Frank E. Todd was sent to the Argentine in 1924 to work on *Schistocerca paranensis*, known in the Argentine as the langosta. This is one of the larger species of migratory locusts which flies south from the tropics each spring, feeding and laying its eggs on the treeless plains of northern Argentine. It is also a serious pest in Brazil, Bolivia, Paraguay, Mexico, and probably other South and Central American countries.

The principal crops of the area invaded in the Argentine are flax, wheat, corn, alfalfa, vegetables, and some fruits. In other sections, cotton, sugar cane, and citrus fruits are attacked by the langosta. All of these crops are in large acreages but by far the largest are planted to wheat and flax. The profit from a hectare (2.471 acres) of flax is about $100 Argentine money, while the profits from the other crops run a little higher but do not exceed $200. With returns such as these it is apparent that control measures are well worth while.

The adults, after wintering in the tropics, fly south in the early spring to lay their eggs. (Fig. 5-7). These are laid in the ground; the soil being packed full of eggs in considerable patches. Immense numbers of small jet-black nymphs, the first instar, hatch in these localized areas. These nymphs are extremely gregarious, rather inactive, and tend to cling in dense black masses on those plants which are their favorite food. The insects of the second instar are essentially like those of the first, but are somewhat more migratory in their search for food. In the evening they gather in swarms that completely cover the vegetation. These two instars, the mosquita stage, comprise the first fifteen days of the insect's life.

The next three instars are known as the saltona stage. They are so called due to the active hopping by means of which they move about in search of food, principally corn and alfalfa. In this stage they spread out over a greater area and are very restless, migrating aimlessly for considerable distances during the day. In the evening they gather again in close masses, often in a convenient straw stack. The appe-

Fig. 5-7. Swarm of Ovipositing Langosta. Argentine, S. A.

tite of the saltona is more ravenous than that of the mosquita. They attack a wide variety of plants, riddling the foliage or devouring the entire plant. (Fig. 6-7). The damage which they do is severe, rapid, and extensive; covering a large area in a short time.

Mr. Todd reached the Argentine at the time when the adult langosta were laying eggs. Cyanogas Calcium Cyanide Flakes and Cyanogas Calcium Cyanide "A" Dust were used in the preliminary experiments against this stage. It early appeared that the adults were very resistant to hydrocyanic acid gas. It seemed practically impossible to secure a satisfactory kill, even when the doses were high enough to severely injure the plants upon which the langosta were resting. The results of these early tests are included in Table I.

The failure of Cyanogas Calcium Cyanide to kill the adult langosta did not discourage the Argentine entomologists. It was their belief that the adults should be allowed to lay their eggs undisturbed, thus localizing the infestation. They felt that the best time for control was the mosquita stage, for at that time the insects were most easily attacked by reason of their habits. The fact that they gathered in dense masses made it possible to apply all the poison where it would do the most good. The mosquita stage was fairly inactive, hence could be approached for treatment without greatly disturbing the swarm.

Table I.

Cyanogas Applications for Control of the Argentine Langosta (*Schistocerca paranensis*)
Frank E. Todd, 1924.

Exp. No.	Place	Stage	Material	Dosage Per 50 Sq. M.	Area Treated	Method of Application	Time	Temp.	Rel. Hum.	% Kill.	Remarks
62	San Justo	Mosquita	Flakes	1,650 grams	30 sq. metres	Broadcast	10:00	54	76	90%	Rain following application released gas rapidly
63	San Justo	"	"	2,500 "	20 " "	"	18:00	55	82	70%	
38	Parana	"	"	4,000 "	3 " "	"	10:00	85	32	0%	Very dry—application too scattered
39	Parana	"	"	24,000 "	½ sq. metre	"	9:00	80	32	10%	Concentration not built up soon enough
60	San Justo	"	A Dust	100 "	5,000 sq. metres	Amer. Beauty Duster	18:00	68	43	75%	
65	San Justo	"	"	357 "	700 " "	"	19:00	64	39	40%	Dosage too light—slight wind
66	San Justo	"	"	1,000 "	200 " "	"	19:00	65	48	75%	
64	San Justo	"	"	1,000 "	50 " "	"	18:30	55	82	Very High	
82	Conesa	"	"	1,250 "	80 " "	Vermoral Duster	18:30	—	—	100%	
81	San Nicholas	"	"	1,250 "	20 " "	"	8:00	.	--	75%	Surrounded by barrier.
67	San Justo	"	"	1,300 "	75 " "	Amer. Beauty Duster	17:30	66	26	75%	Windy—low humidity
83	Capitan Sarmiento	"	"	1,425 "	70 " "	Vermoral Duster	19:30	--	—	90%	
58	San Justo	"	"	2,000 "	25 " "	Amer. Beauty Duster	9:30	66	49	60%	Strong wind weakened concentration
101*a*	San Nicholas	"	Granules A Dust	1,000) 1,000) "	10 " "	Holder's "Tip Top" Duster	18:30	86	—	98%	Dusted until stupefied—Granules then thrown on.
101*b*	San Nicholas	"	A Dust Flakes	1,000) " 1,500) "	11 " "	" Hand	18:30	86	—	98%	Dusted until stupefied- Flakes put on to maintain high concentration.
100	San Nicholas	"	Granular	2,500 "	9 " "	Broadcast	6:30	75	--	60%	Locusts on ground killed—on plants above escaped.
99	San Nicholas	"	"	4,000 "	6 " "	"	6:00	75	—	60%	
85	San Nicholas	Saltona	"A" Dust	935 "	80 " "	Vermoral Duster	19:30	83	—	80%	
96	San Nicholas	"	"	1,250 "	40 " "	"	18:40	86	—	75%	
108	Chivilcoy	"	"	1,500 "	10 " "	Holder's "Tip Top" Duster	16:00	90	—	80%	
107	Chivilcoy	"	"	3,125 "	16 " "	"	16:00	90	—	50%	Wet ground and plants absorbed gas
97	San Nicholas	"	Flakes	1,650 "	167 " "	Broadcast around plants	6:00	74	—	75%	
6	San Justo	Adult	'A" Dust	5,500 "	—	Amer. Beauty Duster	15:00	90	—	10%	Males succumb easier than females
4*c*	San Justo	"	"	11,350 "	11 " "	Spoon	10:00	77	--	72%	
4*a*	San Justo	"	"	17,000 "	15 " "	"	10:00	77		25%	
2	San Justo		"	21,090 "	—	Amer. Beauty Duster	8:00	60	--	0%	
1	San Justo	"	"	23,310 "	—	"	18:00	59		52.5%	
4*b*	San Justo	"	"	31,250 "	4 " "	Spoon	10:00	77		15%	
3	San Justo	"	Flakes	23,310 "	—	Hand	18:30	59		11%	

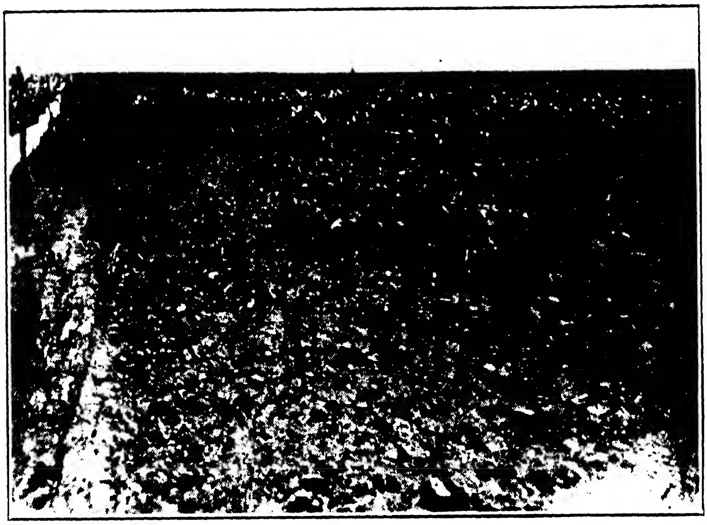

Fig. 67. Cornfield Devastated by Langosta. Argentine, S. A.

Mr. Todd carried out extensive experiments to test the efficacy of Cyanogas for the various immature stages of the langosta, as they developed. He soon discovered that a sufficiently high concentration of gas, that would give a satisfactory commercial kill of the mosquita, could not be obtained by the use of Cyanogas Calcium Cyanide Flakes under the ordinary dry conditions existing in the Argentine. Cyanogas "A" Dust was found to give a much higher kill when applied under favorable atmospheric conditions. When a strong wind was blowing, even with very heavy applications of the dust, poor kills resulted due to the impossibility of building up and maintaining an adequate concentration over a period of time necessary to cause the death of the insects. At the completion of the work on this stage, Mr. Todd was able to state that Cyanogas "A" Dust, applied at the rate of one kilo per 50 square metres would secure a satisfactory kill of the langosta. The dust should be applied under favorable atmospheric conditions such as: calm or very slight wind, fairly high relative humidity, and not too dry soil.

The control of the saltona stage was attempted, following the same procedure as that used against the mosquita. The Cyanogas Calcium Cyanide Flakes again proved ineffective due to the slow evolution of the gas. Cyanogas "A" Dust proved to be more effective against the saltona stage when

dusted, by means of a duster or shaker, over the insects, when they were clustered together for the night. It will be seen from Table I that high doses used against the saltona were not nearly so effective as the same or lower doses against the mosquita. These results bore out very well the previous assumption that the best method of attack would be one directed toward the control of the mosquita stage.

Since the use of Cyanogas Calcium Cyanide Flakes, laid down as a barrier, had proved to be successful in the control of the chinch bug, it was thought that some modification of this method might be used successfully for the control of the langosta. The method recommended by the Argentine government for the control of the langosta was the use of metal barriers, eighteen inches high with corrals at regular intervals. The migrating langosta, in the saltona stage migrated to the barriers, over which they could neither climb nor fly. The direction of migration was then changed and they progressed along the barrier until they were stopped by falling into the corral. This method did not give the desired results as it was too inflexible to meet sudden changes in the migration of the insects. (Fig. 9-7). The barriers were difficult to install, and involved high costs in time and labor at a season when these could least be spared. It seemed that Cyanogas might well be used as a killing agent in conjunction with these barriers.

Mr. Todd carried out a number of experiments to determine whether some variation of the barrier method might not be made effective as a means of control. He laid down barriers of varying widths and concentrations on the surface in front of the advancing swarm of hoppers. Most of the insects were able to pass safely through this gassed area. Cyanogas was then used in ditches of varying depths and although a slightly higher kill was obtained, this method was not effective. The results of his experiments, using barriers against the mosquita and saltona stages, are included in Table II.

Cyanogas "A" Dust was then used with the hope that a better kill might be secured by the use of a material which evolved its gas more rapidly than the Flakes. The dust worked very well when the hoppers were restricted to the gassed area by means of ditches or iron barriers, but as a strip to prevent migration, regardless of width or concentration, it was ineffective. The results of the work with Cyanogas as a barrier indicated that the best method of application

TABLE II.

Barrier Applications of Cyanogas Calcium Cyanide for Control of the Argentine Langosta (*Schistocerca paranensis*)
Frank E. Todd, 1924.

Exp. No.	Place	Stage	Material	Dose Per ½ Sq. M.	Amount Used	Description of Barrier	Time	Temp.	Rel. Hum.	% Kill	Remarks
46	Villa Urquiza	Mosquita	Flakes	31 grams	1 kilo	2 x 8 metre strip	10:00	88	41	0%	Dryness and wind made dosage ineffective.
47	Villa Urquiza	"	"	100 "	½ kilo	10m. x 20cm. ditch	10:30	88	41	0%	Dryness and wind made dosage ineffective.
61	San Justo	"	"	111 "	8 kilos	36m. x 1m. barrier	7:30	52	69	70%	Rain following application increased kill.
43	Parana	"	"	120 "	360 grams	30cm. x 6m. (put in six holes)	10:00	80	32	30%	
50	Villa Urquiza	"	"	150 "	500 grams	10m. x 15cm. x 30 cm.	11:30	88	41	0%	Dryness and wind made this dosage ineffective.
51	Villa Urquiza	"	"	180 "	900 grams	9 holes 20 x 20 cm. each, 1m. apart in a 10m. trench	17:00	88	41	25%	Deeper holes might be more effective
88	San Nicholas	"	"	240 "	3 kilos	2½ sq. metres laid down perpendicular to steel barrier	10:30	90	—	25%	
48	Villa Urquiza	"	"	500 "	½ kilo	1m. long x 50cm. wide x 50 cm. deep-ditch behind iron barrier	10:30	88	41	60%	
57	Villa Urquiza	"	"	500 "	1 kilo	Pit—1 sq. m.—75 cm. deep	10:00	88	30	20%	
59	San Justo	"	"A" Dust	375 "	½ kilo	4 m. long x 15 cm. wide	16:30	81	24	5%	
99a	San Nicholas	"	Granules	29 "	175 grams	3m. x 1m.	6:00	75	—	60%	
99b	San Nicholas	"	"	54 "	325 grams	3 m. x 1m.	6:00	75		60%	
86	San Nicholas	Saltona	Flakes	71 "	2 kilos	2 m. wide x 7 m. long-barrier	9:30	86		60%	Too thin an application.
89	San Nicholas	"	"	205 "	2 kilos	4 rows of 12m. x 10cm.	7:00	72		60%	
93	San Nicholas	"	"	285 "	2 kilos	3½ m. x 1 m. barrier	16:00	90		95%	Covered with straw after application to prevent escape of langosta.
90	San Nicholas	"	"	415 "	2 kilos	4 rows 6 m. x 10 cm.	6:30	68		80%	
91	San Nicholas	"	"	830 "	2 kilos	2 furrows 10cm. x 6 m.	11:30	80		75%	Many escaped by avoiding furrow.

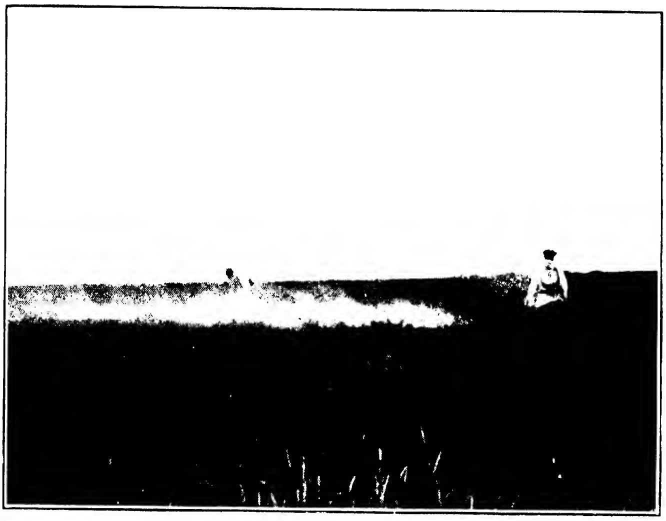

Fig. 7-7. —Application of Cyanogas with Duster for Control of Langosta.

was to dust the insects when they were concentrated in a restricted area.

In view of the successful results obtained in the experiments for the control of the mosquita, it was felt that Cyanogas had a place in the control of locusts in the Argentine. The following year, 1925, our Mr. George G. Wittwer carried out further experiments to determine if improved methods of application might reduce the dosage necessary to give commercial kills. At the conclusion of his experiments he demonstrated the use of Cyanogas Calcium Cyanide before government officials in two official locust tests. Extracts from his reports of these tests follow:

First Official Locust Tests

"On last Tuesday (October 27, 1925) the first official tests for the control of the locusts in the nymph stage were made in the presence of Mr. E. E. Blanchard and S. Emilio Barbesino, who constituted the commission appointed by the Bureau of Agriculture for this work.

"These tests which took place outside of Ataliva (Prov. Santa Fe) were begun at 16:00 and continued to 18:30 o'clock. The day was sunny and a mild wind prevailed. The dry bulb registered 77° and the wet bulb 65°. A Holder's "Tip Top" duster was used in this experiment.

"The mosquita masses, newly hatched and still hatching, were located along the roadside among the weeds. At the beginning of the experiment they were quite spread out as the sun was still high. However, by 16:30 they were congregated in compact patches ranging from 1m.x 1m. to 1m.x 5m. These patches covered 100 square metres and were located in an area 270 metres long by 1 metre wide.

"We had considerable difficulty in spreading a light dosage with the "Tip Top" duster, but were finally able to get it adjusted to spread at the rate of 1 kilo to 50 square metres. In this manner we dusted an area of locusts consisting of 100 square metres with 2 kilos of dust. A kill of 100% was secured. The effect of the gas was instantaneous and during the two and one-half hours that we remained there, no revivals were noticed. We did observe insects hopping into the dusted area, and they were immediately killed by the fumes. The nymphs in this and subsequent experiments seemed to dry up almost immediately after death.

"The commission recommended that further experiments also be made with Cyanogas with a view of ascertaining the cost per square metre for controlling the locust in the various life stages, to find out to what stage this insect could be controlled with Cyanogas on an economical basis, and to make some studies relative to the most economical method of application.

"With this in view it was decided to make further tests against locusts in the nymph stage on Thursday (October 29, 1925) on patches that were entirely hatched. I might say here that the time for hatching this year is taking much longer than during normal years owing to the cold weather which has been prevalent during the entire spring. The eggs took sixty-three days to hatch, and locusts in the mosquita stage were still quite scarce when we went to Santa Fe to make our tests.

"The commission suggested that some experiments against the nymph stage be conducted with Cyanogas "A" Dust diluted with some other ingredient, thereby reducing the cost of treatment. We therefore made preparations the following day to make experiments on the 29th with mixtures of flour, plaster of Paris, and air slaked lime to see which of these would best serve the purpose. A small quantity of each of

Fig.8-7.—Langosta Killed with Cyanogas.

these was secured and screened through a fine sieve. These ingredients were then carefully dried in an oven, packed in glassene paper bags of 100 grams each, and placed in empty Cyanogas tins to prevent the absorption of moisture. The 100 gram bags facilitated mixing in the field just before the experiment and made the control of the amount used for the area treated much easier.

"On the 29th we prepared to leave early in the morning to make some tests against adult locusts in the laying stage, but did not arrive on the field of operation until 12:06 noon. We found the entire roadbed covered with locusts breeding and laying their eggs. Since their wings were very dry, they were very active and could only be approached for treatment with difficulty.

"However, we were able to dust an area of 80 square metres with two and one-half kilos of dust and obtained a very high kill. It was impossible to check up on the percentage, for when the dust was applied many of the locusts either jumped or flew out of the gassed area. We remained there for one and one-half hours and noticed that locusts alighting

Fig. 9-7.—Cyanogas in Conjunction with Barrier. Note Pile of Dead Langosta at Edge of Pit.

in the gassed area were stupefied immediately and died shortly after. After the dust had been distributed, we checked up on the dusted area and found, without exception, that the locusts which had remained in the dusted area were dead. We also experimented with putting a dust barrier on the windward side of small patches of locusts and noted that those remaining in these zones were killed. The commission agreed with us that it would not be difficult to control the laying locust if the material were applied early in the morning or late in the afternoon. They stated, however, that they were not particularly interested in controlling this stage as they preferred to permit them to lay their eggs in localized areas which they might not do if disturbed in the process of laying. Eggs laid in a localized area make the control of the mosquita much easier. The weather during this experiment was alternately cloudy and sunshiny with a mild wind blowing. The dry bulb registered 74° and the wet bulb 64°. A much heavier dosage was required to kill at this stage than in the mosquita stage. (Place: Tacural, Prov. Santa Fe.)

"The next experiment took place outside of Ataliva (Prov. Santa Fe) on the same day (October 29, 1925). The patches treated had entirely hatched out and the insects were from 2½ to 5 days old. The time of application was from 16:35 to 18:30 o'clock. The sun was still shining and there

was practically no wind. The dry bulb registered 75° and the wet bulb 68°. Cyanogas was mixed with flour, plaster of Paris, and air slaked lime. The flour and plaster of Paris had to be ruled out as they contained sufficient moisture to cause a great deal of gas to generate while being mixed with the Cyanogas. Much better results were obtained with the lime although some of this seemed to contain moisture. These mixtures (50% lime, 50% Cyanogas) were applied with a Feeny No. 2 duster (with extension and spreader) and with a sifter.

"With the sifter we treated four patches to ascertain what the effect of the use of a diluent would be. The results were as follows:

Size of Area Treated	Grams Cyanogas	Grams Lime	% Kill
3.3 m. x 2. m= 6.6 sq. m. } 2. " 1. " 2. " " }	100	100	100
5. " x 3. " =15. " "	200	200	100
7. " x 2.4" =16.8 " "	375	375	100
40.4	675	675	

"Of all the methods of application used in these experiments, (Holder's "Tip Top" duster, Feeny No. 2 Duster, and a sifter), it was found that the sifter gave the best results. With a sifter we were able to spread the dosage more evenly and this method had the advantage of placing the material directly on and around both the plants and the insects. Both of the dusters raised large clouds of dust, which left very little material where it could be of value, and did not spread the material as evenly or lightly as was necessary for an economical kill.

"The commission and some other members of the Defensa Agricola who accompanied us dusted several patches, subsequent to the experiment noted above, with 50-50 mixtures and obtained a kill of one hundred per cent in every case. We particularly observed the action of the gas on the few nymphs that hopped into the gassed area. They could not withstand the rapid action of the gas . We dusted a few patches of nymphs with a mixture of one part Cyanogas and two parts lime but this was wholly unsatisfactory as it merely stupefied them for a short time, most of them reviving within ten minutes.

The only question remaining to be solved was a more perfect method of application, entailing a minimum loss of Cyanogas. The sifter which was used was a very crude affair, being made hurriedly by punching holes in the top of a Cyanogas tin with a nail*. These holes were not equal in size and not evenly spaced. The best type of sifter would be one with a mesh sufficiently large to permit distribution at the rate of 1 kilo to 60 or 70 square metres.

"The commission decided to adjourn our experiments until the week of November 15, at which time we should be able to test Cyanogas for the control of more advanced stages of the langosta."

Second Official Locust Tests

"The commission for these tests was composed of Sr. Emilio Barbesino, Sub-Inspector for the Defensa Agricola in Santa Fe and Sr. Hector Millan, Ingeniero Agronomo, whose permanent station is in the fruit districts of Mendoza.

"The first of these tests took place outside of Rafaela, Santa Fe, at 6:00 o'clock on November 17, 1925, in a weedy alfalfa field which adjoined the road. The sun was well up, very little wind, the dry bulb registered 74° and the wet bulb 70°. There was no moisture on the plants. A large mass of insects was located alongside the road and in one corner of the field in the weeds. The commission identified these as being about ten days old. The patch treated covered an area of 240 square metres. Six kilos of Cyanogas were used; five kilos were put on pure and one kilo mixed with an equal amount of cheap talc. The kill was the same in either case. The material was applied with a Holder's "Tip Top" duster, a sifter, and a Cyanogas No. 32 duster. All methods proved equally effective. This patch was checked up on November 20, 1925 and it was found that a kill of one hundred per cent had resulted, with no damage to the alfalfa.

"On November 19th, five masses of locusts, 10 days old, were treated. The time was 6:52 o'clock. There was considerable dew on the grass although the sun was quite high and the wind strong. The dusters used were Holder's "Tip Top", Cyanogas No. 32, and "La Potente", a locally manufactured double action duster. The wind was too strong to permit placing the dust and it also blew the gas away, as the grass was too short to retain the material until a killing concentration could be reached. We also used the sifter with a

* See Fig. 5-6 on page 6-46 for illustration of such a sifter.

50-50 mixture, pure dust and pure Cyanogas G-Fumigant, and the results were negligible. The locusts were located in short pasture grass about 6″ high, where they were already quite active. When we checked up late that afternoon a very spotty kill was observed and the grass where the dusting had been particularly heavy was severely burned.

"In the afternoon of the same day, four large patches of locusts were treated in the same field which had been treated in the morning. The time was 18:13 to 19:30 o'clock. The total area treated amounted to 210 square metres on which 4½ kilos of dust were used. There was very little wind. The ten day old locusts were gathered in dense clusters. The kill was checked up the following morning, November 20, 1925, and it was found that where the dusting had been heavy a kill of one hundred per cent had resulted but where the dusting had been light the kill was negligible. However, no real check could be made as the spots treated had already been invaded by a new lot of the first and second instars.

"The next experiments were carried out in a field just outside of Rafaela where we found locusts in both the mosquita and saltona stages. Temperatures could not be taken but it was evident that the humidity was high. The Savage duster was used and gave splendid results. With this machine the nymphs up to ten or twelve days old were killed with Cyanogas "A" Dust, when applied at the rate of 1 kilo per 50 square metres. For the saltona stage it took practically double this dose. There were six of these masses treated at this time, all located in a weedy pasture. The next morning, November 24, 1925, checking up showed a kill of one hundred percent of the mosquita and that only sixty percent of the saltona had been killed.

"The commission informed us after we returned to Rafaela that they had seen enough experiments with Cyanogas and were satisfied with the results obtained and that they were recommending approval of Cyanogas for the control of locusts up to 10 days old."

Following the report of the commission, the Argentine government gave the official approval for the use of Cyanogas Calcium Cyanide for the control of the langosta.

7-46

Buenos Aires, Marzo 30 de 1926.-

Señor F. Hintermeyer.-

Buenos Aires.

Por la presente hago constar que en los experimentos oficiales efectuados con el compuesto "CYANOGAS" se ha comprobado que dicho producto ha dado muy buenos resultados en la destrucción de la langosta en estado de mosquita, como así mismo en la destrucción de vizcachas, hormigas, ratas y otros insectos, reptiles, anfibios, etc., y que puede ser considerado como un elemento de valía para la defensa de la agricultura y como destructor de toda clase de roedores é insectos y para la desinfección de granos atacados por diversos parásitos.-

Exp-W-5203/925.-

Saludo a Vd. atentamente.-

JT.

TRANSLATION

(The original is typed on a sheet bearing a circular design bearing the inscription: "A. R. Ministry of Agriculture, General Direction of Agriculture and Rural Defense".)

Buenos Aires, March 30th 1926

Mr. F. Hintermeyer,

Buenos Aires:

I hereby make known that in the official tests made with the "CYANOGAS" compound, it has been proven that the said product has given excellent results in the destruction of the locust in the "mosquita" stage, as also in the destruction of vizcachas, ants, rats and other insects, reptiles, amphibians etc., and that it may be considered as an element of the greatest value for the defense of agriculture and as a destroyer of all kinds of rodents and insects and for the fumigation of cereals attacked by divers parasites. File No. W-5203/925.

Yours very truly

(signed) Guillermo Lynch

JT.

(SEAL of the Office of the Director General of Agriculture and Rural Defense.)

Conclusions

1. The sifter is the best method of applying the dust to the mosquita (1-5 days). At this stage they live in a compact mass and can be dusted quickly, easily, and with a small amount of dust.

2. A sifter has the advantage of putting *all* of the dust where it is useful.

3. For the mosquita, a 50-50 mixture of Cyanogas with talc can be used with the same result as was obtained with undiluted Cyanogas.

4. The use of a good duster with Cyanogas "A" Dust is the most effective method for the control of locusts from 5 to 12 days of age.

5. Excellent results can be obtained at this time by using a mixture of 50% "A" Dust and 50% talc if the insects are massed in tall grain, weeds, or grass which are an aid in maintaining a high concentration of the gas. Talc is the only diluent which is advisable to use. Unsatisfactory results are obtained when the masses are located in short grasses.

6. Dust the plants only when the leaves are dry.

7. The best time for dusting is either in the early morning, providing the plants are dry, or late in the evening when there is very little wind and the sun is going down.

Experiments in Spain

At the present time our Mr. Frank E. Todd is carrying out experiments for the control of the Spanish langosta (*Stauronotus maroccanus*). His experiments with the mosquita, thus far, indicate that a higher dosage than that used in the Argentine will be necessary to give complete kills. The nymphs of this species are commonly found in open pastures where there is no tall vegetation to aid in maintaining a high concentration. A dose of about one kilo to 35 square metres appears to be necessary to give results under these open conditions. The results of his early work against this species are given in Table III.

TABLE III.

Experiments Against the Mosquita Stage of the Spanish Langosta, *Stauronotus maroccanus*

Frank E. Todd—1926

Exp. No.	Place	Time	Temp.	Wet Bulb	Weather	Material	Dosage Per 50 Sq. M.	Area Treated	Method of Application	% Kill	Remarks
131	Vilches	12:00	72	60	Moderate wind	"A" Dust	200 grams	3 sq. metres	Cyanogas Knapsack Duster	0%	Application much too light.
130	Vilches	12:00	72	60	Moderate wind	" "	600 "	3 " "	Holder's "Tip-Top" Duster	50%	325 killed in 3 sq. m.
140	Linares	16:00	--	--	Heavy wind	" "	1,000 "	50 " "	Remodeled Cyanogas Knapsack Duster	15%	Large amount of dust blown away by wind.
142	Linares	9:00	62	61	Cloudy	" "	1,250 "	72 " "	" "	80%	Moisture of soil aided in rapid evolution of the gas.
144	Linares	8:00	52	51	Cloudy, soil wet	" "	1,650 "	30 " "	" "	95%	Moisture of soil aided in rapid evolution of the gas.
139	Linares	11:00		—	Clear, windy	" "	1,650 "	30 " "	" "	80%	— — - - - - - -
128	Vilches	9:00	70	60	Moderate wind	" "	1,650 "	3 " "	Holder's "Tip-Top" Duster	80%	1,175 killed in 3 sq. m.
141	Linares	8:30	62	61	Cloudy	" "	2,000 "	50 " "	Remodeled Cyanogas Knapsack Duster	90%	- - — — --- -
143	Linares	6:30	51.5	50	Soil wet	" "	2,000 "	85 " "	" "	95%	Moist ground gave rapid evolution of gas.
129	Vilches	10:00	71	60	Moderate wind	" "	2,150 "	3 " "	Holder's "Tip-Top" Duster	90%	1,410 killed in 3 sq. m.
127	Vilches	8:30	72	60	Clear	" "	3,300 "	6 " "	Holder's "Tip-Top" Duster	90%	Dose heavier than necessary to secure this kill.

Grasshoppers in the United States

In the western part of the United States, experiments have been carried out for the control of the immature stages of migratory grasshoppers, principally those of the species *Camnula pellucida* Scudder.

Tests with Cyanogas Calcium Cyanide Granules and Cyanogas Calcium Cyanide "A" Dust were carried out in the Antelope Valley in California by our Mr. Stanley W. Bromley. The Granular material was distributed by hand, by means of a sifter and, and a wheelbarrow seeder with a 14 foot boom. Cyanogas was effective when applied at the rate of 200 to 300 pounds per acre. The heavier dosages were required for the older nymphs. The wheelbarrow seeder greatly increased the area that could be treated at once but was found to require constant refillings.

Cyanogas Calcium Cyanide "A" Dust, when applied by means of a duster was just as effective as the Granular material Wind decreased the effectiveness of the "A" Dust to a greater extent than it did that of the Granular material. Tall grass increases the effectiveness by acting as a windbreak, thus maintaining a high concentration of gas for a longer period of time.

Fig. 10-7. Application of Cyanogas with Wheel-barrow Seeder for Control of the Clear-winged Grasshopper.

LOOSE I-P LEAF

CLASS No. 4 CATALOG COVER

TELESCOPING BACK

PATENTED